DRILLING AND PRODUCTION | PIPE LINE | REFINING NATURAL GASOLINE

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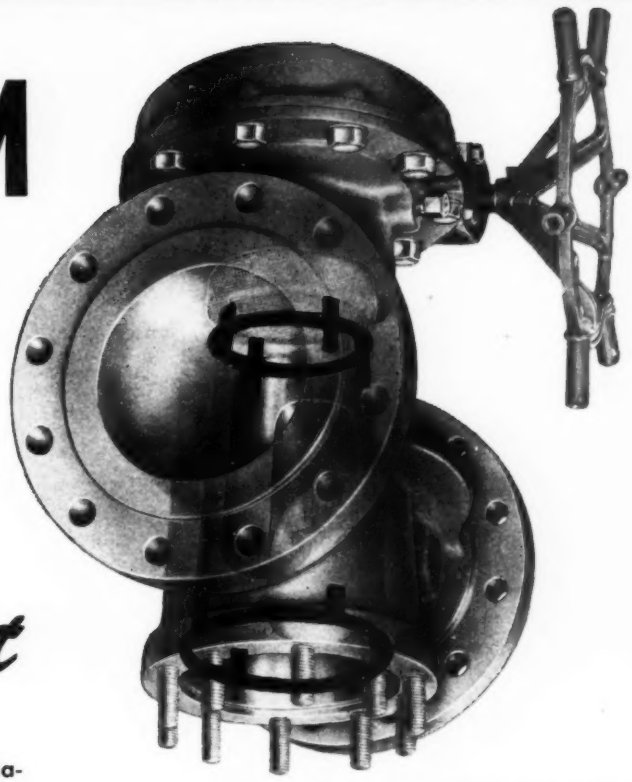

Lubrication in Nordstrom Valves is a vital factor. In combination with other important features lubrication adds greatly increased valve life. Lubricant, applied under pressure, permits jacking of the tapered plug to allow free turning. It forms a positive seal around the ports. Abrasion is successfully resisted. Nordstroms present the surest control on mud lines, manifolds, Christmas trees, pipe lines, etc.

The Nordstrom Hypreseal Valve, shown in phantom, illustrates the "Sealdport" lubrication system.

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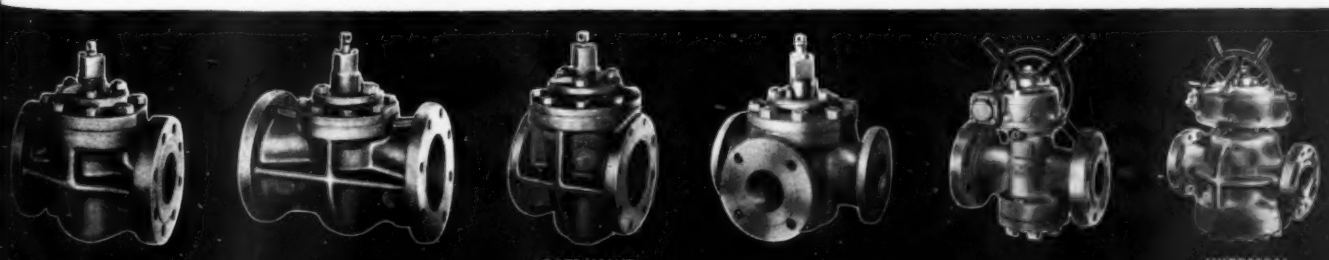
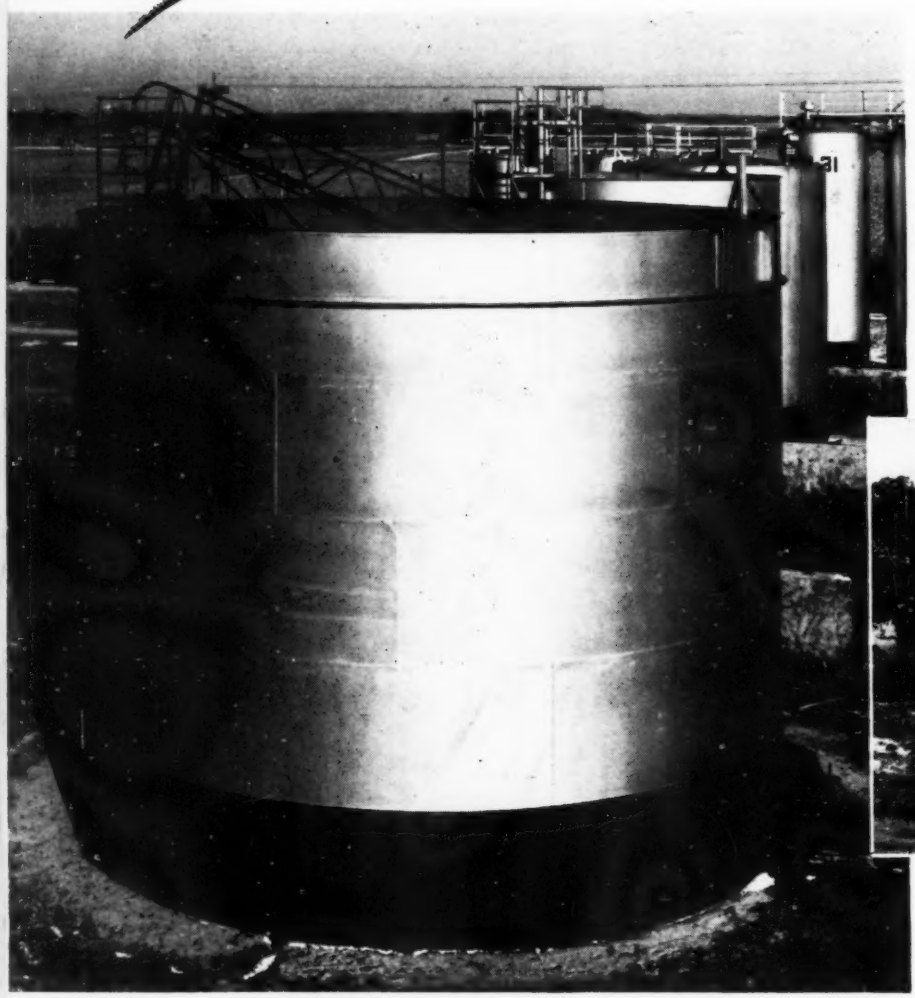
KEEP UPKEEP DOWN

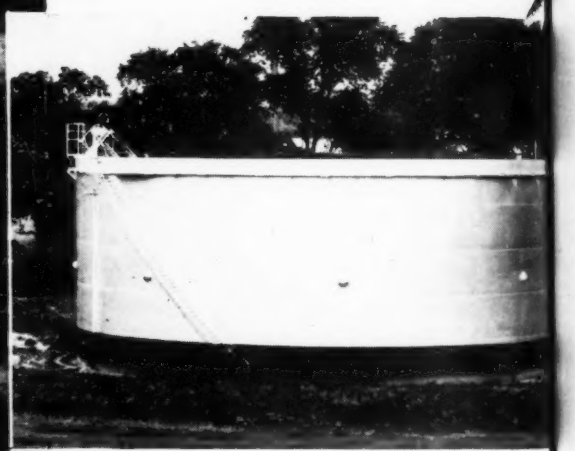


REGULAR | VENTURI | GATE VALVE REPLACEMENT | MULTIPORT | HYPRESEAL | HYPRESEAL ROUND OPENING

. . . for fast-working
tanks . . . use WIGGINS

Pontoon Roofs





The Wiggins Pontoon Roof installations shown are located at pipe line stations. The tank directly above is 100 ft. in diam. and has a capacity of 55,000 bbls. The photo at the left shows two tanks equipped with Wiggins Pontoon Roofs, one of 5,000-bbl. capacity and the other 2,000 bbls.

. . . and Stop evaporation at its source . . .

There's an efficient vapor-saving device for every type of service. In addition to studying the recommendations below we suggest you write our nearest office for more specific information on your own particular storage problems.

VOLATILE HYDROCARBONS IN FULL STANDING STORAGE TANKS

On new tanks use—Wiggins Balloon Roof or Breather Roof.

On tanks with roofs in good condition use —new Wiggins Piston Balloon.

On tanks requiring new roofs use—Wiggins Balloon Roof or Breather Roof.

VOLATILE HYDROCARBONS IN SLOW-WORKING TANKS

On new tanks use—Wiggins Balloon Roof or Hortonsperoid.

On tanks with roofs in good condition use —new Wiggins Piston Balloon.

On tanks requiring new roofs use—Wiggins Balloon Roof.

VOLATILE HYDROCARBONS IN FAST-WORKING TANKS

On new tanks use—Wiggins Pontoon Roof.

On tanks with roofs in good condition use —new Wiggins Piston Balloon.

On tanks requiring new roofs use—Wiggins Pontoon Roof.

THE problem of storing volatile liquids in tanks that are filled or emptied more than six times a year—without experiencing excessive vapor loss, may be efficiently solved by the use of Wiggins Pontoon Roofs. These devices are especially well suited for use on tanks handling any grade or blend of gasoline that does not boil at atmospheric temperature.

Recent improvements in the design of the Wiggins Pontoon Roof have increased its efficiency in preventing evaporation losses. The roof floats directly on the liquid, blanketing the surface at all levels and eliminating the active vapor space in the tank — thus preventing all filling losses and practically all breathing losses. It also reduces boiling losses by trapping vapor formed below the liquid surface and retaining it until cooler temperature causes reabsorption.

Wiggins Pontoon Roofs may be installed on new or existing riveted or welded tanks over 15 ft. in diam. Full information on this and other vapor-saving devices is available upon request. Write our nearest office.

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PROCESSED IN COPPER, STAINLESS STEEL OR OTHER ALLOYS

The balancing bar a circus tight rope walker carries helps to maintain equilibrium. Ring Controlled Expansion Joints as made by the Badger Fire Extinguisher Company will maintain equilibrium in a pipe line, reliably compensating for expansion due to variance in temperature, as well as vibration due to axial movement.

Ring Controlled Packless Expansion Joints, made by the Badger Fire Extinguisher Company, are available with single or multiple corrugations, in flange or weld types. Special attention is paid to the elimination of stress and strain in the metal, and there is a wide range of metals and alloys for steam, air, liquid, or gas lines, according to your need.

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MEETINGS

September 7—California Natural Gasoline Association, monthly meeting, Rio-Hondo Golf Club, Downey, Calif.

September 11-15—American Chemical Society, fall meeting, Pennsylvania Hotel, New York, N. Y.

September 20-22—NPA, annnual meeting, Hotel Claridge, Atlantic City, N. J.

October 2-5—American Society of Mechanical Engineers, fall meeting, Cincinnati, Ohio.

October 3-4—AAODC, annual meeting, Fort Worth, Texas.

October 3-5—National Safety Congress, Sherman, Morrison and La Salle hotels, Chicago, Ill.

October 5-6—American Gas Association, Stevens Hotel, Chicago, Ill.

October 9-11—IPAA directors meeting, Dallas, Texas.

October 13—California Natural Gasoline Association, annual meeting, Biltmore Hotel, Los Angeles.

November 9,10—Society of Automotive Engineers, National Fuel and Lubricants, Mayo Hotel, Tulsa, Okla.

November 15-19—American Chemical Society, third national chemical exposition, Coliseum, Chicago, Ill.

January 8-12—Society of Automotive Engineers, annual meeting, Book-Cadillac Hotel, Detroit, Mich.

March 12-14, 1945—National Association of Corrosion Engineers, President Hotel, Kansas City, Mo.

★ Meetings of A.P.I., Texas Mid-Continent Oil and Gas Association, and I.P.A.A. have been indefinitely postponed at the request of the Office of Transportation.

★ ***A spotlight is thrown on trends in the national petroleum scene by the new Petroleum Engineer presentation of statistics. In connection with a comprehensive picture of the statistical facts published each month there will be an analysis of the figures, pointing out the trends that may be indicated and suggesting where they may lead. Another page contains 12 charts that show at a glance the national changes that have developed.***

★ Gasoline in colors may be the fashion in days to come. In Argentina, where gasoline is more scarce than here, truck owners must buy only gasoline that is colored blue and private cars must use yellow gasoline for rationing checkup.

THE Petroleum Engineer

August, 1944
Vol. XV No. 12

A MAGAZINE OF METHODS FOR OPERATING MEN

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The Treasury Department acknowledges with appreciation the publication of this message by:

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Back the Attack!

SELL MORE THAN BEFORE!

THE PETROLEUM ENGINEER

This is an official U. S. Treasury advertisement prepared under the auspices of Treasury Department and War Advertising Council

The Course of Oil

K. C. SCLATER

AN AUSPICIOUS AGREEMENT

Just as the oil industry of the United States is about to commemorate its 85th anniversary, an agreement on petroleum has been reached between representatives of the United States and the British governments. From what is known at present this agreement has all the earmarks of becoming a propitious document. It heralds the beginning of a new era in world oil development. It provides for setting up an International Oil Commission somewhat along the lines of the Oil States Compact, membership in which eventually will include representatives of all nations possessing petroleum resources. An international forum will thus be provided for a free discussion of problems pertaining to the world development of oil and to insure the availability of oil supplies to all nations in amounts adequate for national security and economic well-being.

A highly important provision of the agreement is one directly concerned with field operations. This provision has to do with good development and production practices. It states that "supplies should be derived from the various producing areas of the world with due consideration of such factors as available reserves, sound engineering practices, relevant economic factors, and the interests of producing and consuming countries and with a view to the full satisfaction of expanding demand." Here is a recognition of the benefits to be derived by taking into account reservoir conditions, economic factors, and the interests of producing and consuming countries.

Whether this agreement meets with universal acceptance is perhaps not so important. What is important is that such an agreement could be reached at this preliminary stage. It is a long step toward clearing the air in regard to international oil development and should have sympathetic consideration by the world oil industry in general. The principles outlined in the agreement give full cognizance to the soundness of following modern enlightened oil field development practices and the benefits that can accrue thereby to national economic welfare.

OIL'S ENVIABLE RECORD

The petroleum industry of the United States will be 85 years old this month. A brilliant chapter in industrial progress and technical advancement has been written by oil during these 85 years. Petroleum has had a profound influence on human progress. "Nothing man has taken from the earth has changed human life so quickly and so extensively as petroleum. Gold, sought through the ages, is but a dead metal, an inanimate token for other things, goods and services, for whose utility it can offer in itself no substitute. Oil, on the contrary, is alive, pulsing with living power capable of being harnessed by man for a thousand beneficial purposes. The discovery of gold in California and Alaska enriched but a comparatively few. The discovery of oil lengthened the days and widened the horizon of all mankind."

Miracles accomplished by the petroleum industry under the inordinate demands of war will, when the full story can be told, be just cause for pride in an industry whose life's span covers a scant 85 years.

SUBSIDIES IN CALIFORNIA

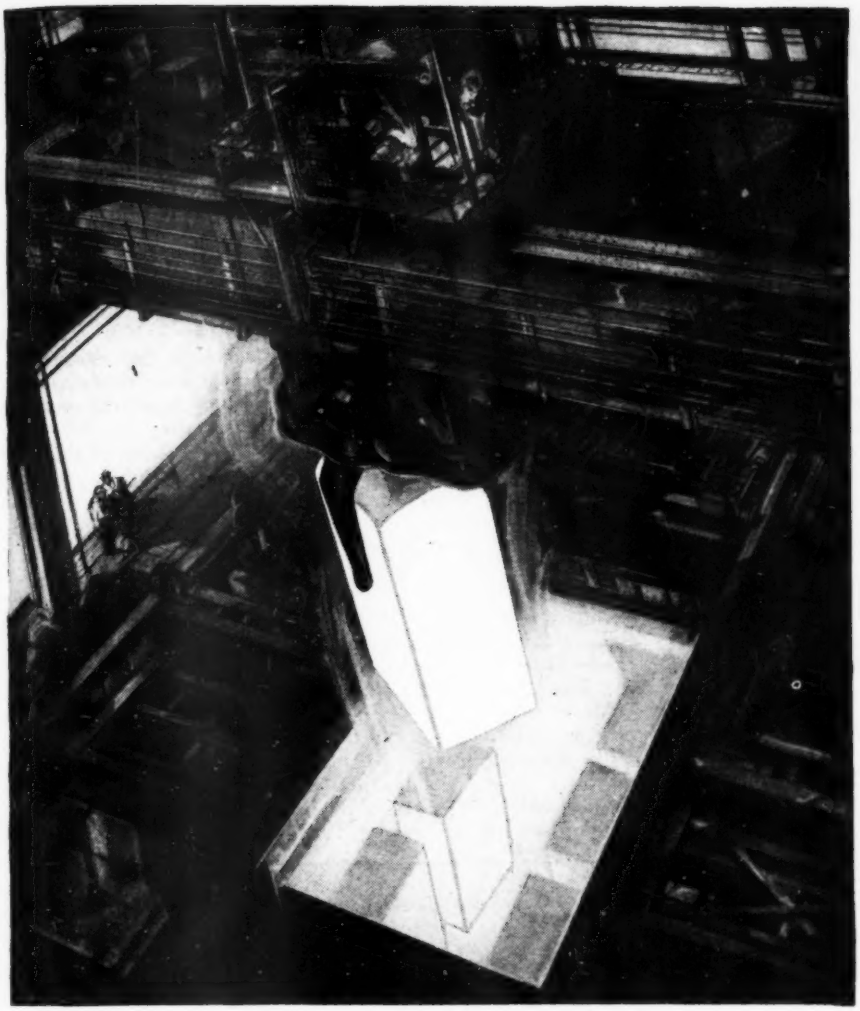
Many specious arguments have been advanced by opponents to a general price increase for crude oil and its products. The *Independent Oil Producer*, California, in discussing this opposition and the question of stripper well subsidies so far as it applies to oil operators in that state, points out that "an emotional argument is used by the opponent of price increase to-wit: That many companies already are in a profitable position under the existing price, and that an increase * * * will help the 'major' companies. The situation is analogous to that of the farmer who refused to feed his milk cows because some of them were already fat.

"Whatever profits the 'major' companies may now make on their current production operations, nevertheless even they should not be compelled to sell their past discoveries at less than replacement costs. Is this whole thing a design to level off the prosperous, even if it completely destroys the struggling man at the bottom of the ladder?

"No, says the Office of Price Administration. We don't want the independent oil producer to pass out. We will give him money enough to make up for his losses. We will call it a subsidy. During the depression we called it relief. Now we will set the pot of gold on the White House steps and let the 'little operator' come and get his dole.

"The joker is that the plan for subsidy, when finally announced, did no such thing. It provided a gratuity for certain small wells, most of which were owned by large and prosperous operators. The independent is not necessarily the owner of a small well. He is the owner of a small property, or properties, but his wells will not necessarily be 5- or 7-barrel wells.

"The situation in California is illustrative: May 1, 1944, the proposed subsidy plan would apply to 41 fields or zones only, with a production of 21,546 barrels per day. Of this production the majors own or control 73.22 per cent (15,779 barrels) while 216 independents control 26.67 per cent or 5,747 barrels."



BAPTISM OF FIRE
FOR STEEL INGOTS

The baptism of fire that steel ingots receive in the great gas-fired furnaces, known as soaking pits, conditions them for further processing. It is one of the many applications of heat in the production of steel. For heat is the agent that reduces raw materials into iron, converts iron into steel, helps shape and finish steel into the infinite number of forms in which it serves.

In the manufacture of steel, great progress has been made in the study, analysis, and control of heat. The attention paid to the application of heat is as careful as that paid to the scientific determination of the materials used in producing steel, the most useful of metals—steel to arm our fighting men with superior weapons—steel in abundance for broader peace-time employment.

JONES & LAUGHLIN STEEL CORPORATION
PITTSBURGH, PENNSYLVANIA
J&L STEEL

CONTROLLED QUALITY STEEL FOR WAR

SOAKING PITS

Holes in the ground were the first device for evenly distributing throughout the steel ingot, the heat from its molten interior to its solid exterior, to make it ready for rolling. John Gjers, Swedish-born steel engineer of England, in 1882, seeking to avoid time-wasting, costly practice of allowing ingots to cool and then reheating them to rolling temperatures, placed each ingot in a brick-lined, covered hole in the ground. These heat-retaining holes, forerunners of modern, complex steel ingot-heating furnaces, were called "soaking pits." The holes have long been obsolete, but the name lingers on.

Gjers' idea was successful from the start and the new practice spread from England to the Continent and to the United States within a dozen years. The Henry Bessemer medal was awarded Gjers in 1894 by the British Iron and Steel Institute "for great service" to the industry by his soaking-pit invention and other improvements in iron and steel production.

The baptism of fire given steel ingots today in modern, intricate, scientifically heat-controlled and skilfully tended ingot, heating furnaces, is a far cry from the holes in the ground put to use by the son of a Swedish army officer in England back in the 80's. The soaking of ingots in pits is one of the most important steps today in the march of steel from iron ore to finished product. Without soaking pits there could not have been the present record production of steel for war—90,000,000 tons last year in the United States, more than all the rest of the world.

Shriller than a bo'sun's in a gale, is the whistle piercing the deep undertones of a steel mill that is the signal to start ingots coming up from the soaking pits to the blooming mill to be rolled into long blooms or wide slabs. After this first rolling, the steel passes on through other mills and other processes to wind up in many sizes, shapes and grades adaptable for manufacture of countless articles useful in peace, as well as war.

Only 15% of surgical instruments sold in this country before the war were made here. Now most instruments and hospital equipment for our armed forces are American made. The industry is producing about 60,000 tons of special steels for some 5,000 applications required by Army and Navy Medical Corps. This entailed learning how to achieve production of many highly specialized steels formerly imported from Europe.

Conquering new horizons in metallurgy since World War I, American scientists have put the U.S.A. far ahead in production of better industrial steels, and in development of super-fine special steels. For example they have (1) Created new high temperature and corrosion-resistant steels for hospital and laboratory; (2) Helped make possible the mass fabrication of these steels into surgical instruments of unparalleled efficiency; (3) Materially aided vast life-saving developments within the pharmaceutical industry.

National Petroleum Situation

War's effect upon the petroleum industry in the first seven months of 1944 ***is reflected by sharp increases recorded over last year*** in practically all basic factors.

Drilling, production, and processing are materially higher than last year, while ***demand for war products continues to surge forward*** to the degree that ***stocks are being reduced to all time low levels.***

Today's stocks, in terms of demand, ***present a picture of startling significance.*** All ***refined stocks*** are 5% greater than a year ago, but measured in terms of current demand ***are actually 7% less*** than last year's stored supplies. ***Crude oil stocks*** are 6% under last year, but measured by current requirements ***represent a supply drop of 16%. Motor fuel stocks*** are 10% above last year, but ***5% smaller on a current demand basis. Fuel oil stocks*** are 4% below last year in volume, but ***11% less in terms of current demand.***

Despite record-breaking production and processing of crude oil, war ***demands dictate the necessity for even greater productivity*** if the industry is to provide necessary and reasonably adequate inventories of crude refined products. Under present production schedules the ***industry's combined stock position stands at 83.7% of required levels.*** Accordingly, ***crude oil production and refinery processing are still 4.4% and 4.8%, respectively, below the levels necessary*** to meet current demand and stocks.

Drilling activity is 27% greater than last year, but it is expected that the ***industry will further step up its field operations*** to exceed the previously prescribed quota of 22,000 wells to be drilled this year. Results for the first seven months indicate that ***well completions lagged over 1,200 under the quota,*** which placed the drilling status to date at 90.8% of the prescribed level. Yet, ***new drilling operations on August 1 were 54% above last year*** and point to ***further increases in well completions.***

Increased motor fuel production in response to heavy military demand is ***augmented by increased yields of gasoline from crude oil.*** Refineries in July produced 40.1% gasoline from crude against only 36.7% a year ago. At the same time ***refinery runs to stills have increased 21%*** over last year.

With ***stocks of refined products below requirement levels*** there is need for a further increase in processing of crude. This is particularly desirable in view of ***deeper cuts in light fractions, which reduce the production of fuel oils.*** The ***fuel supply outlook next winter continues unfavorable.*** Official reports from the East Coast indicate that ***stocks of this product are about 2,000,000 barrels below normal requirements.***

Texas led the nation in the first seven months of this year with an ***increase of 36% in daily average crude oil production.*** All other states contributed a combined increase in production of only 1.3%. Decreased production was recorded by Oklahoma, Kansas, Mississippi, Illinois and most of the East.

Crude oil prices, unchanged since the establishment of O.P.A. ceilings, ***are 37.4% below the level of all wholesale prices,*** exclusive of subsidy payments. On the basis of the Bureau of Labor combined index of wholesale prices, ***the average price of crude oil in the United States should be $1.95*** instead of $1.22, which is 62.6% of normal.

Moves are under way in Washington to increase prices for some commodities, but a ***deaf ear continues to be turned to the oil producers' pleas for necessary price increases.*** The realization that ***state gross production taxes cannot be collected on subsidy values*** is not taken lightly by leading oil producing states. ***More will be heard*** in that direction soon. ★ ★ ★

Comparative Statistics, July, 1944

*All figures are computed on a Bureau of Mines basis.**

	July§ 1944	June§ 1944	July 1943	This year to date	Last year to date	Per cent change
Total wells drilled	1,985	1,864	1,551	11,916	9,374	+ 27
Development wells	1,611	1,527	1,255	9,786	7,597	+ 29
Oil	1,101	1,052	798	6,819	4,930	+ 38
Gas	214	196	132	1,170	933	+ 25
Dry	296	279	325	1,797	1,734	+ 4
Per cent dry	18.4	18.3	25.9	18.4	22.8	+ 4.4
Wildcat wells	374	337	296	2,130	1,777	+ 20
Oil	49	39	58	260	241	+ 8
Gas	6	17	11	69	30	+130
Dry	319	281	227	1,801	1,506	+ 20
Per cent dry	85.3	83.4	76.7	84.6	84.7	— 0.1
Wells drilling	4,150	4,070	2,695	4,150	2,695	+ 54
Crude production	144,485	138,170	127,493	958,961	836,835	+ 15
Daily average	4,661	4,606	4,113	4,502	3,947	
Refinery runs	143,000	141,369	120,689	954,292	789,177	+ 21
Daily average	4,613	4,712	3,893	4,480	3,723	
Natural gasoline production	†8,500	†8,414	7,487	†57,455	51,357	+ 12
Daily average	274	280	242	270	242	
Motor fuel production	63,570	62,102	51,044	420,063	331,950	+ 27
Daily average	2,051	2,070	1,647	1,972	1,566	
Gasoline yield, per cent	40.1	39.0	36.7	38.9	36.3	+ 2.6
Crude demand	145,850	144,196	132,199	981,855	850,068	+ 16
Daily average	4,705	4,807	4,264	4,610	4,010	
Motor fuel demand	64,283	64,182	55,699	412,264	333,496	+ 24
Daily average	2,074	2,139	1,794	1,936	1,573	
Fuel oil demand	55,725	55,450	51,439	426,256	361,965	+ 18
Daily average	1,798	1,848	1,659	2,001	1,707	
Crude oil stocks	232,650	235,774	248,625	232,650	248,625	— 6
Days supply	49	49	58	49	58	
Motor fuel stocks	75,075	75,788	67,959	75,075	67,959	+ 10
Days supply	36	35	38	36	38	
Fuel oil stocks	88,170	81,814	91,431	88,170	91,431	—
Days supply	49	44	55	49	55	
All refined stocks	238,337	231,394	227,872	238,337	227,872	+ 5
Days supply	50	48	54	50	54	

*Unless otherwise stated, all figures represent thousands of barrels.
§June and July, 1944, figures are estimates.

Economic Position of Petroleum Industry

First seven months, 1944.

	Normal	Actual	Per cent of normal
Wells completed	13,125	11,916	90.8
Production (thousand bbl. daily)	4,709	4,502	95.6
Refining (thousand bbl. daily)	4,704	4,480	95.2
Stocks, crude and refined (thous. bbl. daily)	562,620	470,987	83.7
Price of crude oil (thous. bbl. daily)	$1.95	$1.22	62.6

Crude Prices by States for July, 1944‡

U. S. average	$1.22	Louisiana	$1.20
Texas	1.23	Arkansas	1.25
California	1.07	New Mexico	1.04
Oklahoma	1.17	Mississippi	1.10
Kansas	1.17	Illinois	1.37
		Other States	1.89

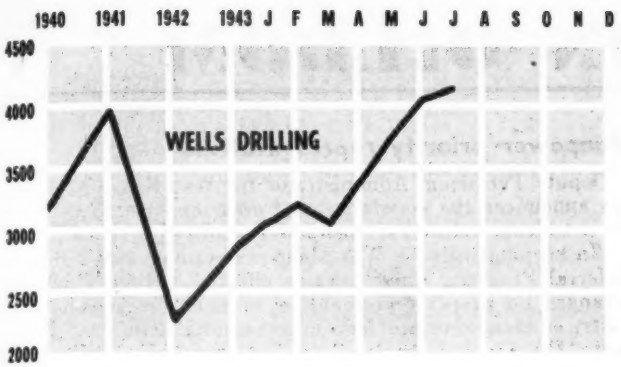
Basic crude prices

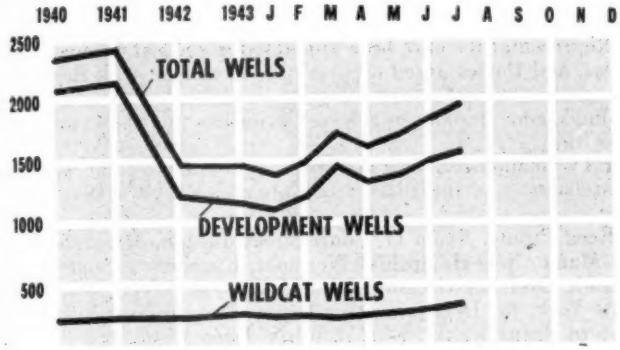
Oklahoma-Kansas (36 gr.)	$1.17
Texas Gulf Coast (36 gr.)	1.40
East Texas	1.25
West Texas (36 gr.)	1.04
Calif., Signal Hill (26 gr.)	1.11
Pennsylvania Bradford	3.00

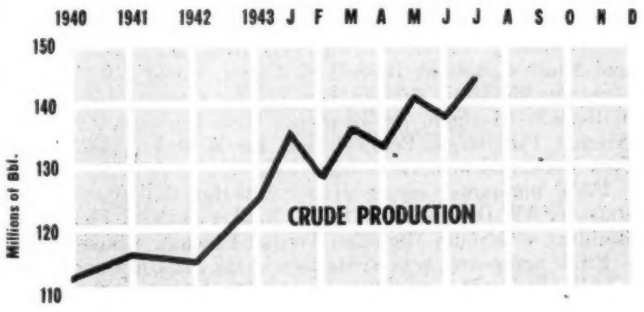
Drilling and Production Statistics by States

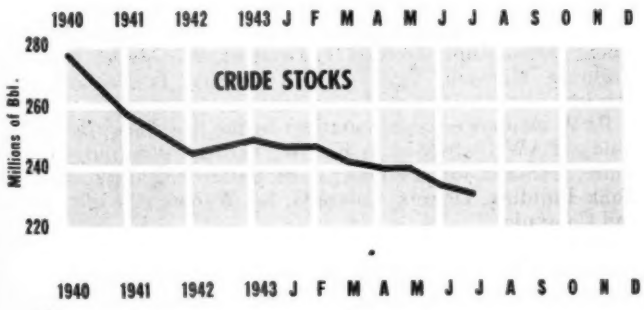
	July§ 1944	June§ 1944	July 1943	This year to date	Last year to date	Per cent change
Total wells drilled	1,985	1,864	1,551	11,916	9,374	+ 27
Texas	517	510	418	3,040	2,185	+ 39
California	169	159	114	1,117	725	+ 54
Oklahoma	150	135	90	896	638	+ 40
Kansas	182	173	143	1,024	905	+ 13
Louisiana	74	56	66	420	384	+ 9
Arkansas	38	21	21	166	137	+ 21
New Mexico	26	33	19	234	120	+ 95
Mississippi	16	10	9	77	52	+ 48
Illinois	163	160	152	958	977	— 2
Other States	650	607	528	3,984	3,251	+ 23
Wildcats drilled	374	337	296	2,130	1,777	+ 20
Texas	119	119	103	764	619	+ 23
California	36	20	10	131	113	+ 16
Oklahoma	37	31	18	197	167	+ 18
Kansas	44	51	41	289	259	+ 12
Louisiana	10	9	10	79	74	+ 7
Arkansas	5	1	9	34	34	0
New Mexico	1	5	0	39	27	+ 44
Mississippi	13	2	5	51	17	+200
Illinois	42	40	43	198	230	— 14
Other States	67	59	57	348	237	+ 47
Daily crude production	4,661	4,606	4,113	4,502	3,947	+ 13
Texas	2,100	2,052	1,625	1,977	1,455	+ 36
California	860	849	776	835	773	+ 8
Oklahoma	343	336	334	335	340	— 1
Kansas	309	270	290	277	300	— 8
Louisiana	355	380	337	357	332	+ 8
Arkansas	80	80	77	80	74	+ 8
New Mexico	108	107	109	111	101	+ 10
Mississippi	43	42	51	42	54	— 22
Illinois	215	220	218	216	230	— 6
Other States	248	270	296	272	288	— 6

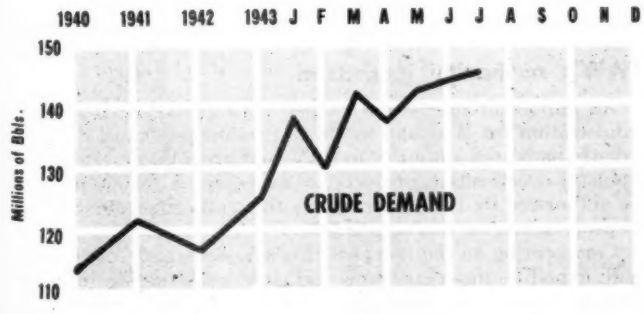
†Includes benzol.
‡No change since prices frozen. Prices do not include subsidies.

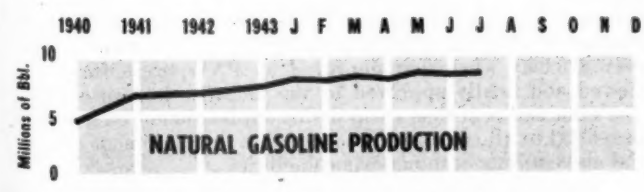


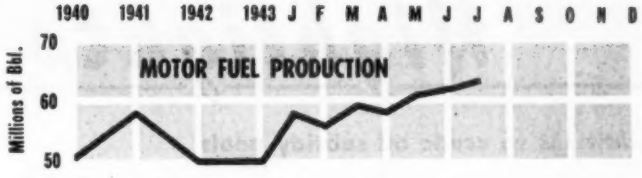


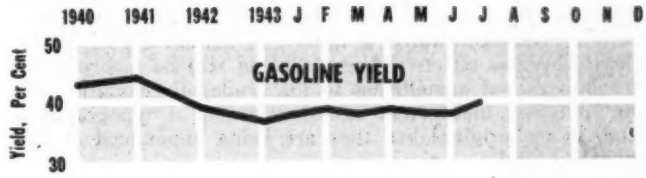


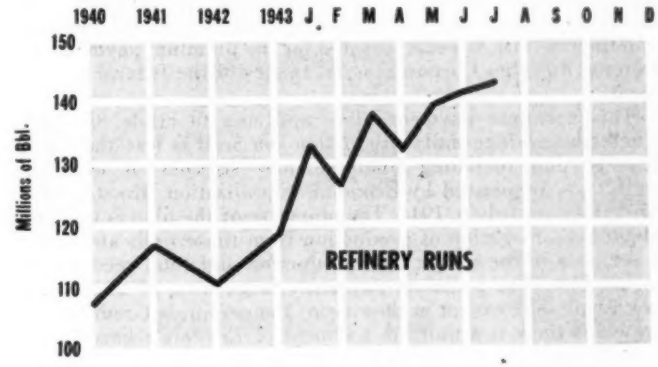


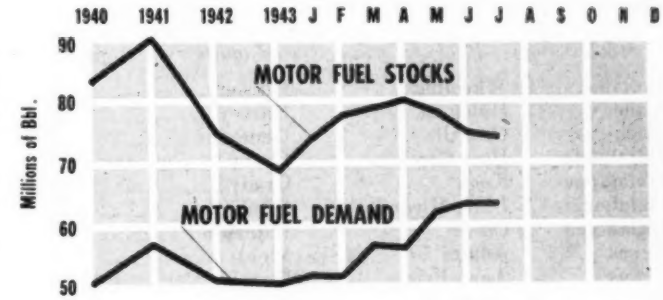


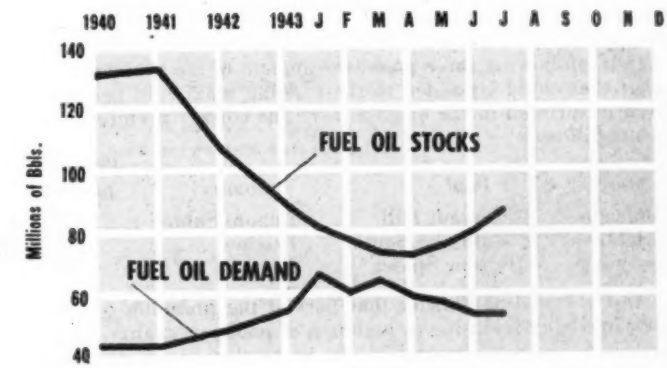


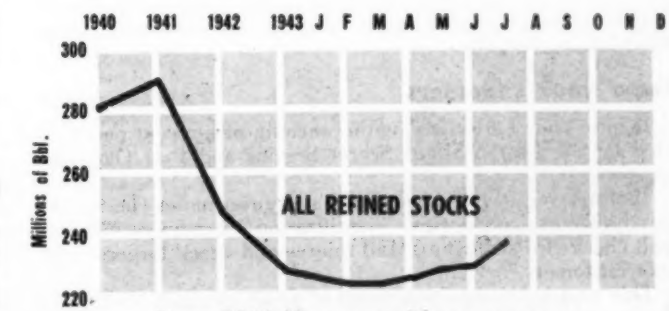












Years 1940-43 are monthly averages.

Highlights IN OILDOM

Additions to crude oil subsidy pools

Thirteen additions and three corrections to the list of crude oil pools that may add premium payments to their maximum prices have been announced by the Office of Price Administration. These changes, which, as in the original list of pools issued July 10, became effective August 1, and will be incorporated later into formal amendment to the crude oil regulation. As they represent inadvertent omissions from, or typographical errors in the original list, they are being announced at this time, OPA said.

Only producers and owners of royalty interests can increase their maximum prices by the amounts of the premium payments. First purchasers of the crude oil pay the added amounts, and they in turn, are compensated for the premium payments by Defense Supplies Corporation, an agency of the federal government.

This premium payment plan, applying to crude oil pools where the average daily production per well is less than nine barrels, and including predominantly stripper or marginal wells, was announced by Economic Stabilization Director Fred M. Vinson on July 6, 1944. The objective of the plan is to bring about a prolongation of production from these wells and cause a net gain in the nation's oil production and total recoverable oil reserves. The premium payments range from 20 to 35 cents per 42-gal. bbl. except in the case of Pennsylvania Grade crude, on which there is a uniform payment of 75 cents a barrel.

Following are the 13 pools added to the original list as embodied in Amendment 2 to the crude oil regulation, Revised Maximum Price Regulation 436:

State	*Pool*	*County*	*Premium payment*
Indiana	Wheeling	Gibson	.35
Kansas	Halstead	Harvey	.20
Michigan	Otisville	Genesee	.20
Oklahoma	Deer Creek	Grant	.25
Oklahoma	Knox	Grady	.25
Oklahoma	Little River East	Seminole	.20
Oklahoma	Oscar	Jefferson	.25
Texas	Adami	Webb	.35
Texas	Agna Prieta	Duval	.35
Texas	Angleton	Brazoria	.35
Texas	Aviators	Webb	.35
Texas	Lost Lake	Chambers	.35
Texas	Marion Co. Shallow	Marion	.35

In the following three pools, the amount of the premium payment that could be added to the existing maximum price had been misprinted in the original list. The correct premium payments follow:

State	*Pool*	*County*	*Premium payment*
Louisiana	Pleasant Hill	DeSoto-Sabine	.35
Oklahoma	Watumka South	Hughes	.35
Wyoming	Poison Spider	Natrona	.25

As OPA will administer that part of the premium payment plan involving inclusion or omission of pools, or changes in the premium payments applicable to particular pools, producers and owners of royalty interests should address all correspondence regarding the eligibility of pools for premium payments to the Petroleum Price Branch, Office of Price Administration, Washington 25, D.C.

Know your endorsers

"Know Your Endorsers" is the warning of a recent poster issued by the United States Secret Service and Post Office Inspectors.

"Before you accept commercial and government checks, demand absolute and positive identification," it advises. "Do not cash checks for strangers. Mail thieves and check forgers make poor customers."

This warning comes as a result of great increases recently in checks signed and cashed by forgers and thieves.

Manpower priority representatives

Deputy Petroleum Administrator for War Ralph K. Davies has announced the appointment of area representatives to aid the petroleum industry on manpower priority problems.

"In keeping with the War Manpower Commission's Priority Referral Program, which became effective July 1, PAW has arranged for proper representation to assist the petroleum industry on manpower problems in its essential activities," Davies said. "These include crude oil production, refining, drilling, exploration, natural gas-gasoline, pipe-line transportation, wholesale distribution, wholesale marketing, warehousing, and terminal operations."

Representatives have been appointed in each of the five PAW areas, and Davies urged oil operators to consult with the PAW manpower representative on the establishment of manpower ceilings and manpower referral priorities for their essential activities.

PAW manpower representatives appointed for the 17 East Coast states and the District of Columbia (PAW's District 1) are:

Reed Prouty, Room 17, Court Street, Boston, Massachusetts, for Maine, New Hampshire, Vermont, Connecticut, and Rhode Island; Ovel Lee Gregory, Jr., 122 East 42 Street, New York, New York, for Delaware, New Jersey, eastern New York, and eastern Pennsylvania; Karl P. Wirth, Room 6646, New Interior Building, Washington, D. C., for Philadelphia; John O. Blakely, 1254 O'Sullivan Building, Baltimore, Maryland, for Maryland, Virginia, and the District of Columbia; John Dozier, Liberty Life Building, Charlotte, North Carolina, for North Carolina and South Carolina; Russell H. Caven, Room 319, Mortgage Guaranty Building, Atlanta, Georgia, for Georgia and Florida; William N. Horigan, 700 Benedum-Trees Building, 221 Fourth Avenue, Pittsburgh, Pennsylvania, for West Virginia, western New York, and western Pennsylvania.

PAW manpower representative covering the 15 midwestern states (PAW District 2) is H. W. Nankervis, 12th Floor, Blum Building, 624 South Michigan Avenue, Chicago, Illinois.

PAW manpower representatives in the six Gulf Coast states (PAW District 3) are: R. A. Heard, 148 Archer Street, Shreveport, Louisiana, for Shreveport, New Orleans, and Lake Charles, Louisiana; J. R. Rives, 416 North 21 Street, Birmingham, Alabama, for Birmingham and Mobile, Alabama, Vicksburg and Biloxi, Mississippi; Gordon T. Granger, 245 Mellie Esperson Building, Houston, Texas, for Arkansas, Texas, and New Mexico.

PAW manpower representatives in the five Rocky Mountain states (PAW District 5) is Ray W. Varnum, 855 Subway Ter-Butte, Montana, for Montana; A. M. Ballard, 320 First National Bank Building, Denver, Colorado, for Wyoming, Utah, Idaho, and Colorado.

PAW manpower representatives for the five Pacific Coast states (PAW District V) is Ray W. Varnum, 855 Subway Terminal Building, 417 South Hill Street, Los Angeles, California.

PAW's authority increased

An important agreement reached between the Petroleum Administration for War and the War Production Board delegates greatly increased authority to PAW and provides that petroleum industry construction projects not exceeding $100,000 may now be authorized by PAW. Previously this authority extended only to projects not exceeding $25,000.

Commenting on the fact that this new delegation of authority will expedite the petroleum industry construction program, Deputy Petroleum Administrator Ralph K. Davies said: "Approximately 95 per cent of all construction project applications received from the petroleum industry are within the $100,000 bracket. In the past, industry construction project applications over $25,000, when first approved by PAW, were further reviewed and finally approved by the facilities bureau of WPB. The elimination of time spent in this duplication of effort will be beneficial to all concerned and expedite the movement of material and equipment to important facilities.

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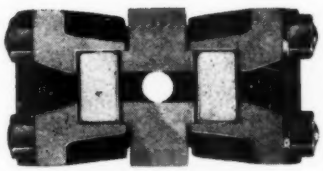

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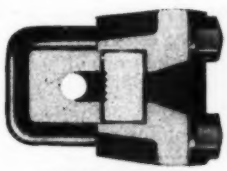

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Reflex
DROP FORGED STEEL LIQUID LEVEL GAGES

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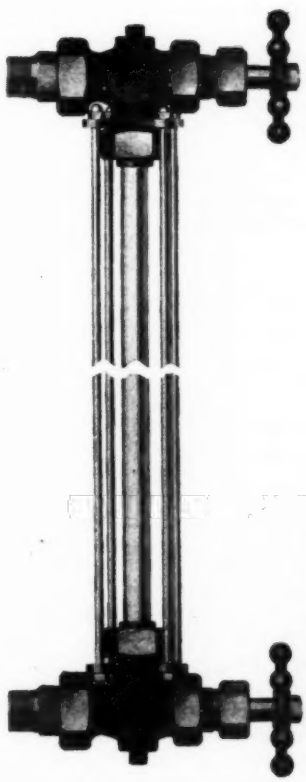

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MAJOR *Oil Field* ACTIVITIES

▼ **TEXAS:** The first Smackover lime oil producer in Texas was brought in by the Barnsdall and Sohio Oil companies in Bowie County. It is the No. 2 Heilbron, N. H. Janes survey, and gauged 80.4 bbl. of oil in 19 hr. by production tests from 7716 ft. The strike has been described as significant by oil men.

Mid-Continent Petroleum Corporation has made a major oil discovery in Andrews County with a well making 150 bbl. of 40 gravity sweet oil an hr. through ¾-in. choke, from the Devonian line, an entirely different producing horizon than that found in other wells in the area. The well is the No. 1 University Tract 7, section 20, Block 13, University of Texas survey, 10 miles northwest of the town of Andrews and 5 miles south of the Fullerton pool. Depth of the well is 8955 ft.

The Sohio Petroleum Company, subsidiary of the Standard Oil Company of Ohio, discovered its first producer in Texas at its No. 1 Garvey in northern Young County. The well, located 3 miles north of Farmer and 660 ft. south of the Archer County line, flowed 163 bbl. of oil in 5 hr. on the initial test. It is producing from the Caddo lime section at 4464-85 ft. and is in the center of a 1500-acre lease block.

Another wildcat discovery well is the Sun No. 1 Sullivan in Brooks County. The well flowed at the rate of 17 bbl. in 18 hr. on ⅛-in. choke from the Vicksburg sand at 8508-17 ft. Pressures were 1150 lb. on tubing and 1700 lb. on casing.

Standard Oil Company of Texas No. 1 Dent, Lease No. 2, block 2387, TE&L survey, is showing for a possible discovery from the Marble Falls in Young County. Operator ran a 30-min. drillstem test from 4274 ft. to 4283 ft., with recovery of 475 ft. of oil and 40 ft. of oil-cut mud.

The Sun Oil Company No. A-3 Bodeker-State, located in survey 16, is a small producing wildcat that opens a gas-condensate field in Brooks County. The well made 1,072,500 cu. ft. of gas and 3 to 4 bbl. of fluid, 90 per cent distillate, per day from sand perforated at 6160 to 6167 ft.

Northern Ordnance, Inc., has opened a new pool in southwestern Young County with its No. 2 F. H. Robertson. The well flowed 155 bbl. of 42-gravity oil on official gauge from the Marble Falls basal Pennsylvania sand from 4175 to 4180 ft.

Dirks Brothers' A-1 Robinson, southwest quarter of section 6, C. W. Hahl subdivision, a Bee County wildcat about midway between the West Tuleta field and the Dirks field, is producing from the Pettus sand at 3982-3996 ft. On test in open hole it flowed an estimated 25 to 30 bbl. of fluid daily.

An entirely new conglomerate pool by Continental and Sinclair No. 1 Hundley in Montague County, 1½ miles southwest of Mallard and 10 miles east of Bowie in the D. Martindale survey produced 275 bbl. of oil in 5 hr., on a ¾-in. choke. Drilled to 8018 ft., the well was perforated and is producing in the conglomerate at 6228-35 ft.

Probable new discovery is the No. 1 Young, SW NW NE of 9-19-1w, in the Orlando-Stillwater area of northwestern Payne County. Operated by Frank Russell, it is good for 50 bbl. a day or more in the Misener sand.

George W. Strake No. 1 Tom O'Connor, ¾ mile south of the Teleferner field in Victoria County, classed as a wildcat, has been completed for 36 bbl. of oil daily on the pump at 2834-44 ft.

▼ **OKLAHOMA:** Sinclair Prairie has opened a new Prue sand pool in Creek County 1¾ miles east of the Stroud pool and the same distance south of the town of Milfay. It is No. 1 Daniel Watson, NE SE 34-15-7, which flowed 170 bbl. of oil in 13 hr. from the Prue sand at plugged back depth of 2643 ft. It drilled originally to 3972 ft. in the Wilcox sand.

Ed Kubat and associates No. 1 Dixon, NE SW SE of 9-3n-1e, in the Pauls Valley area of Garvin County, is a new discovery. On a drill stem test from 3475 to 3491 ft., with tester open one minute, it showed an estimated 5,000,000 cu. ft. of gas.

Deep Rock Oil Corporation, No. 1 Sanders, NE SE SE 17-7-11, Hughes County, indicates a new pool about 5 miles from Horn's Corner. It cored from 4215-32 ft. and recovered 17 ft. of sandy lime and shale with the last foot sand, probably the Cromwell. The lower 3 ft. of the core had a strong odor of oil.

Extending the new East Pauls Valley pool of Garvin County a half mile northwest, the Gilmer Oil Company, may have opened a new sand zone on its No. 1 Stufflebean, SW SW SE 7-3-2. The well showed for an estimated 50 bbl. of oil a day in the Pennsylvanian at 2985-3005 ft. Deepened to 3073 ft. the well picked up a new sand and made a flow up into the derrick before being shut in for tanks. Some believe the deeper pay is the Bromide sand zone.

▼ **ALABAMA:** Alabama's second oil pool was discovered with the No. 2 Robert T. Land wildcat in Choctaw County. It was drilled by the H. L. Hunt Company and is located at the center of section 36-11n-5w. It was drilled to 5400 ft. and then plugged back to 2800 ft. and the casing perforated opposite the Selma chalk for completion. Reports are that the discovery may flow, and at least will make a small pumper.

▼ **ILLINOIS:** Cameron Oil Company's No. 1 Bizot, 30-1s-2e, in Jefferson County, 2 miles southwest of the Dix pool, has set casing to the Benoist sand after recovery of 410 ft. of clean oil on a 40-min. drillstem test at 2042-59 ft.

National Associated Petroleum Company's No. 2 V. Johnson, 10-5s-7e, 2 miles southwest of the Bungay field in Hamilton County, swabbed 7½ bbl. of oil an hr. while cleaning out in the Aux Vases sand at 3387 ft. The new pool opener was drilled one location west of the No. 1 V. Johnson, abandoned as dry.

The Texas Company opened a discovery pool with its No. 1 E. Kasban in the SE SE NW 8-2s-1e, about 12 miles northwest of Mt. Vernon. The well has been put on the pump for initial production test of the Rosiclare sand from 2116-28 ft. It is expected to complete for over 200 bbl. of oil daily.

The oil string has been set to the Aux Vases sand at H. R. Randall No. 1, U. S. Coal and Coke, 14-5s-2e, a wildcat 6 miles northwest of Benton, after recovery of 205 ft. of clean oil on a 1-hr. drillstem test at 2697-2715 ft.

▼ **INDIANA:** Cherry and Kidd, Inc., No. 1 Baird, a wildcat in SWC NE of 25-3s-1e, near Owensville in Gibson County, southwestern Indiana, had the Ste. Genevieve lime at 2485 ft. and the McCloskey from 2513 to 2527 ft. Getting a good show of oil, a drillstem test was undertaken from 2511 to 2517 ft. and made gas in 12 min. and at the end of an hour test it had yielded 30 ft. of oil. On a swabbing test it made 144 bbl. of oil and 12 bbl. of water.

▼ **LOUISIANA:** The Cotton Valley Operators' Committee No. 1 Gray, center of section 26-21n-10w, Webster Parish, is the most important discovery in North Louisiana this year. It flowed 150 bbl. of 70-gravity or better water-white condensate with gas flow of 15,000,000 cu. ft. daily, from a new sand from 10,668 ft. to 10,681 ft.

Union Oil of California has opened a new gas-condensate pool in Vermilion Parish in the Freshwater Bayou area. It is the No. 3-C Louisiana Furs, 34-15s-2e, with a total depth of 12,327 ft.

▼ **ARKANSAS:** The Carter Oil Company, Mid-Continent producing subsidiary of Standard Oil Company of New Jersey, has opened the first Smackover lime gas-condensate pool for Union County, Arkansas. It is the No. 1 G. W. Wilcox, section 33-16-18w, 2 miles north of the Mount Holly pool. The well produced 75 bbl. of condensate from 6985-98 ft. and was reported to have had 100 ft. of porosity in the Smackover section.

▼ **KANSAS:** Phillips Petroleum Company opened a new pool, the Peach, at the No. 1 Chaloupka, SE SEC NW 25-16-14w, in Barton County. It drew an initial rating of 144 bbl. of oil daily from the Arbuckle.

Skelly Oil Company opened a new pool in Pratt County at the No. 1 Shaw, a wildcat in the NW NWC 4-29-13w, 6 miles south of Pratt. Production is from the Arbuckle lime. Some 3500 ft. of oil stands in the pool.

Dickey Oil Company has opened a possible third gas pool of the year in Barber County. It is the No. 1 Hargis, in the center of the east line, SE SW 3-31-14w, 2½ miles northwest of the Lake City pool. At 4395-4417 ft. in the Marquoketa, the well is showing for about 12,000,000 cu. ft. of gas daily.

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MAJOR *Pipe Line* ACTIVITIES

CONNECTS FRANNIE FIELD. PAW has authorized the construction of a 7-mile 8-in. pipe line by the Oklahoma Pipe Line Company between Frannie, Wyoming, and Warren, Montana. This line will deliver oil from the Frannie field to the Warren station of the Yale Oil Pipe Line system now under construction, for delivery to the Carter Oil Company refinery in Billings, Montana. Construction will begin soon.

TO INCREASE CAPACITY. The recently-constructed 231-mile Hugoton natural gas pipe line in Oklahoma has been authorized by the Federal Power Commission to increase its capacity from 140,000,000 to 213,000,000 cu. ft. per day. At the same time the commission authorized the Cities Service Gas Company, Bartlesville, to operate the $9,000,000 Hugoton line until June 30, 1954, under lease from Cities Service Transportation and Chemical Company, Ponca City, Oklahoma, which built the 36-in. line.

The Hugoton line, which was built to relieve natural gas shortage in the Oklahoma-Kansas-Missouri area, carries fuel eastward from the Hugoton gas field in Texas county, Oklahoma, to the Blackwell station of the Cities Service Gas Company. The latter company serves Kansas City, St. Joseph, Joplin, and Springfield, Missouri; Kansas City, Lawrence, Leavenworth, Wichita, and Hutchinson, Kansas, and many other communities.

Facilities authorized include short pipe lines to collect gas from 37 new natural gas wells, which will be drilled in the Hugoton field, and carry it to the main pipe line.

BEGIN FIRST MISSISSIPPI LINE. The first Mississippi crude oil trunk pipe line as a possible forerunner of extensive pipe line construction for the state, which is gradually developing as an oil-producing region of importance, will be constructed by Oklahoma Pipe Line Company, subsidiary of Standard Oil Company, New Jersey. PAW has granted permission for the company to build a 17-mile, 8-in. pipe line from the 10,000-ft. Cranfield (Natchez) pool in southwestern Mississippi westward across the Mississippi River to a barge loading terminal at Gibson landing in Concordia Parish, Louisiana. The new line is expected to be ready for operation by December 1.

The pipe line will mark a new era in the Mississippi oil production, now totaling 45,000 barrels daily. The supply has been moved entirely by rail, truck, and barge. The Oklahoma Pipe Line is taking 1500 bbl. of oil daily from the Cranfield pool and moving it via tank-car through Mobile. It also purchases oil in the Pickens, Eucutta, and Heidelberg pools.

The Gibson landing barge terminal has been in existence for some time. It is owned by Standard Oil Company of Louisiana and is already handling substantial quantities of petroleum for movement up the Mississippi by barge, now being moved by several companies for their northern refineries.

BUILDING LINE IN CHINA-BURMA-INDIA. For the purpose of transporting oil to the allies, a new oil pipe line is being built in the China-Burma-India war zone by the United States army engineers. Work on this project has been going on for months and is progressing satisfactorily, the war department has announced. The location, extent, and personnel of the line have not been revealed.

When finished the new pipe line will bring vast supplies of oil for the war to Allied troops from a great distance, thus eliminating the hazards of surface transportation. The line will create a new route, which may be the beginning of oil development in a part of the world heretofore industrially undeveloped.

Another laurel for American industry, the pipe line is the culmination of repeated surveys by army engineers, many of whom felt that it would not be possible. Chief engineer is a Texan who believed the project possible, identified formerly with a major oil company in the Southwest. He was in civilian war work, but the army gave him a uniform and colonel's eagles, with instructions to carry through the project.

TEXAS-WEST VIRGINIA LINE PROGRESSES. Scheduled for operation in the fall of 1944, over a half of the 1200-mile 24-in. pipe line of the Tennessee Gas and Transmission Company being built from Corpus Christi, Texas, to Cornwall station, West Virginia, has now been completed. The project was authorized by the Federal Power Commission on September 24, 1943, to afford relief to the Appalachian area. Work on the 23-spread project was slowed down in the spring by rains, but additional crews have been added and work is now progressing at an average of 10 miles per day. Stations in Monroe, Louisiana, and Batesville, Mississippi, have been almost completed, and other stations are 35 to 80 per cent completed. Most major items of equipment have been delivered.

HOBBS GETS NEW LINE. Pipe line outlets for the Hobbs field in southeastern Crane County, West Texas, and the Russell pool in northwestern Gaines County, West Texas, have been authorized. The Texas-New Mexico Pipeline Company will lay a 3-mile, 4-in. conduit from its McCamey station in Upton County to the Hobbs area. Atlantic will install 5 miles of 4-in. line from the Wasson-Hobbs 6-in. trunk line to the Russell production.

TO SHIP OIL WEST. Secretary of the Interior Harry L. Ickes has proposed to ship from 30,000 to 40,000 bbl. of West Texas sour crude oil by tank car to California. The oil would be used to help plug a deficit caused by declining crude stocks in that state.

In reply to the proposal, L. M. Glasco, secretary-treasurer of Pacific War Emergency Pipe Lines, commented:

"As we predicted months ago when we pleaded for authorization to build a pipe line from the Permian Basin in West Texas and Southwest New Mexico to California, Mr. Ickes now begins to realize that oil for a war effort powerful enough to smash the Japs may be another case of too little, too late.

"The proposed line could be laid in four months and it could move around 175,000 bbl. daily in a steady stream. Oil hauled by rail tank cars will have to pay the freight rates, which are greatly in excess of the cost of moving oil by pipe line. The public will have to pay the freight."

The line proposed by Glasco's firm would extend 980 miles from Monahans, Texas, to Beaumont, California.

REPORTS ON PIPE LINES. Ohio Oil Company has purchased some 83 per cent of the right-of-way and staked 84 per cent of the 115-mile, 8-in. products line from Robinson, Illinois, to Indianapolis, Indiana, with completion scheduled for October or November, reports PAW. Progress on other projects are:

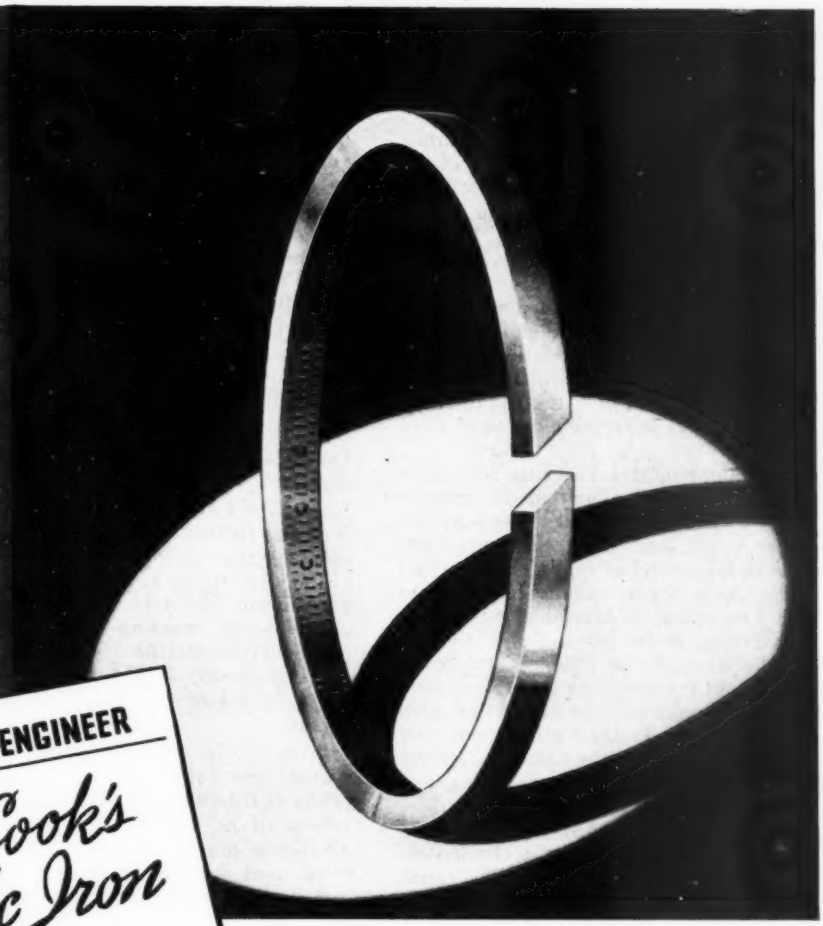
The 34-mile, 6-in. Texas Company's line from Lockport, Illinois, to East Chicago, Indiana, has 96 per cent of pipe strung and 74 per cent laid. Buildings and machinery foundations for pump stations in Lockport are completed and buildings 80 per cent finished, with project completion expected this month.

The 6-in. Yale's Elk Basin line from Elk Basin to Warren, Montana, has been tested to 900 lb. and filled with crude. Twenty-eight miles of pipe have been strung and 24 miles laid on 8-in. line from Warren to Yellowstone River near Billings. The pump house at Yellowstone station is completed and equipment installed. At Warren station, the pump house foundations are laid for building and equipment has been connected. Equipment has been set on foundations and building erection will start soon at Elk Basin station. The project is scheduled for completion this month.

Pan American's 36-mile 3-in. crude line from Willamar to Port Isabel, Texas, has approximately 15 miles of pipe laid. Progress has been retarded by the breakdown of construction equipment and inability to obtain repair parts. Work of erecting pump station has been started, and the completion date should be this month.

Construction work by Utah Oil Refining Company of 112 miles of 6-in. crude pipe line from Iles Dome Pool, Colorado, to Wamsutter station, Wyoming, will begin in September. The project should be completed by December or January.

Reduce cylinder wear



MEMO from **CHIEF ENGINEER**

Order Cook's Graphitic Iron Piston Rings

AUTHORITIES differ as to the major cause of cylinder wear. But all are in agreement that the cost of cylinder wear together with the expense of cylinder and ring replacements in industrial size Diesels, constitute the major expense item on the maintenance sheet. Assuredly many variables enter the picture, but there is one thing certain—if piston rings could be dispensed with, little wear would occur. It is apparent then, that the piston rings to use are rings specially engineered to minimize wear. COOK has specialized in this all important phase of piston ring development for over 20 years, with the result that COOK'S GRAPHITIC IRON Piston Rings come as near to being frictionless as rings can be. If you do not have the full story of COOK'S GRAPHITIC IRON, write for special bulletin, but better still—to reduce the rate of cylinder wear in your engine, on your next requisition, instruct your buyer to order COOK'S GRAPHITIC IRON Piston Rings. If you need help do not hesitate to call on COOK'S engineers.

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MAJOR *Refining* ACTIVITIES

COMPLETES TWO PLANTS. Atlantic Refining Company has completed a huge fluid catalyst cracking plant at its Point Breeze refinery at Philadelphia, Pennsylvania.

A similar cracking unit, now being built at the company's refinery at Port Arthur, Texas, has also been completed. This plant will mark the end of a construction program of aviation gasoline equipment, begun early in the war period, in which The Atlantic Refining Company has invested more than $22,000,000.

The fluid catalyst cracking process is the newest development in the production of aviation gasoline. Company engineers say that when the emergency demand for combat grade aviation fuel ends, these plants can be converted to the production of high octane gasoline for civilian motor needs.

The structure at Point Breeze, complete with fractionating towers and supplemental equipment, covers an area the size of two football gridirons placed side by side, and towers into the air the height of a 22-story office building.

Many of the production difficulties normally encountered in the starting up of such a huge unit may be eliminated, here and at Port Arthur, as the result of such a huge unit may be eliminated at both places as the result of continuous tests conducted since last year in a pilot unit installed at Point Breeze to reproduce in small scale the operating conditions of the big cracking plants.

The entire structure of the cracking unit is welded and it is believed to be the largest welded structure in existence involving steel sections of such weight.

An idea of the magnitude of the unit at Philadelphia is conveyed by these facts:

The catalyst regenerator weighs more than 1,000 tons under operating conditions and its base is 130 ft. above ground.

The weight of structural steel required to support the refining units totals 1700 tons, and the total weight of plate steel in the refining units is approximately 1400 tons.

There are about 50 miles of pipe in the unit, the largest being 82 in. in diameter.

The largest of the 13,750 valves in the unit weighs about 9 tons.

The water requirements for cooling and condensing are equivalent to the requirements of a city the size of Scranton, Pennsylvania, and the power requirements equal to that of a city the size of Pottstown, Pennsylvania.

More than 5000 drawings were prepared specifically for the construction job, and nearly 1,000,000 sq. ft. of blueprint paper was used.

CHEMICAL PLANT FOR SHELL. J. Oostermeyer, executive vice president of Shell Chemical Division of Shell Union Oil Corporation, has announced that the War Production Board has authorized construction of an allyl chloride and allyl alcohol plant at Houston, Texas. Construction is to begin at once. The new type plant is the result of many years of research and development work on the part of Shell Development Company. While allyl chloride and allyl alcohol will have many interesting uses in the synthetic chemical industry, it is expected that immediate application of the output of the new plant will be in the field of plastics for aircraft and war material construction.

INCREASES OUTPUT. The new $12,000,000 catalytic cracking plant of the Union Oil Company of California will increase further the company's output of 100-octane gasoline before the end of the year, Reese Taylor, president, has announced. He told the semi-annual stockholders' meeting that the company's modernization project in Wilmington is one of the nation's largest privately financed wartime refinery programs.

"Among the new units to be completed," he said, "are a combination crude distillation and cracking unit, the newest of its type in the country; an alkylation plant and isomerization unit to be used in aviation gasoline production and redistillation and treating facilities."

POSTWAR PRODUCTION. At least 50 per cent of the 100-octane gasoline plants will be discontinued after the end of the war, in the opinion of John C. Day, Tulsa, Oklahoma, executive manager of the Western Petroleum Refiners' Association. Testifying at a hearing of the Senate special middle west fuel committee, he expressed the opinion that most airlines would continue to use 91-octane gasoline and that the automotive industry would not increase materially the octane requirements of postwar cars.

"I believe," Day said, "that the high octane requirements after the war will be less than 35 per cent of our present refinery capacity." He said that his association now was conducting an experiment to determine if distillates from 100-octane production could be used as a heating field.

BEGINS CYCLING PLANT. The Shell Oil Company, Inc. recently announced that construction of a cycling plant near Sheridan, Colorado County, Texas, is now under way. The Sheridan area is a Wilcox field with production coming from zones around 10,000 ft. deep.

The plant will have an initial daily capacity of 100,000,000 cu. ft. of gas and is expected to produce approximately 6000 bbl. of war products daily. The war products consist of isobutane, normal butane, isopentane, normal pentane, natural gasoline and condensate. Sixty-four hundred horsepower will be used in the engine room for recompression purposes. The contract for the plant was awarded Petroleum Engineering, Inc., of Houston. The plant is expected to be in operation by spring.

TO ADD EQUIPMENT. Authorization for expenditures totaling $2,336,606 for additions to the 100-octane gasoline facilities in southern California has been announced by the Los Angeles Area Production Urgency Committee, according to Louis M. Dreves, chairman.

The 10 projects recommended by PAW are:

Addition of two tank mixing units at Mohawk refinery, Barkersfield, for handling 100-octane gasoline production—$4800.

Steam boilers at Standard Oil Company El Segundo refinery in connections with aviation gasoline production—$198,000.

Replacement of rail facilities at General Chemical Company El Segundo plant for use in 100-octane production—$102,000.

Construction of cafeteria at Standard Oil El Segundo refinery for employees making products used in 100-octane and synthetic rubber production—$160,000.

Installation by Union Oil Company of spare pumping units at Los Angeles for 100-octane program at refinery—$10,325.

Installation of 20,000-gal. propane storage tank for General Petroleum Corporation—$14,000.

Erection of garage building by California Butane Company at Maywood for heavy transportation equipment used to truck butane and other critical petroleum products—$17,204.

New storage tank at Tide Water Associated Oil Company at Santa Maria for Santa Barbara County refinery—$4277.

Construction or replacement facilities at Dow Chemical Company's Torrance styrene plant for production of ethylbenzene, critical component in production of 100-octane gasoline and synthetic rubber—$1,796,000.

Installation of reboilers at Shell Oil Company at Wilmington refinery, for processing of aviation gasoline.

CANOL PROJECT. Standard Oil Company of Alaska, with headquarters at Whitehorse, Yukon Territory, Canada, will continue to operate and maintain the United States government's Canol refinery and the pipe line system in Alaska, the Northwest Service Command announced recently. It will also be responsible for maintenance of the pipe line access road from the wells to the refinery. It will not, however, have jurisdiction or control over the dispensing and price of products nor over the price of petroleum products.

The Canol project is the subject of a congressional subcommittee whose members were appointed recently.

THE Petroleum Engineer

AUGUST, 1944

Design, Construction, and Operation Of Salt Water Disposal System

By L. H. DIAL*

Latest open-type system in East Texas serves 84 producing wells—10,000 bbl. per day

The giant East Texas field long has been a laboratory for many problems of production among which is that of salt water disposal. Since the organization of the East Texas Salt Water Disposal Company in 1942 the strides in that field have been rapid. Staffed by men already acquainted with methods used by other companies in East Texas and other fields, the Salt Water Disposal Company has been progressive in the development of the technique of salt water disposal.

Beginning with its first system in October, 1942, the growth of the company has been rapid and steady. During the month of July, 1944, that company alone injected in excess of 6,000,000 bbl. of salt water into its own 27 disposal wells. During the month of August, 1944, two additional wells will be completed and put on injection.

Recently a disposal system known as the W. S. Morris System was placed in operation. It represents the latest in the design of open-type systems installed by the company to date. It serves 84 producing oil wells and acts as a relief to the Suman system, which serves 104 oil wells. It is located in the W. B. Davis survey in Upshur County. The designed capacity of the plant, 10,000 bbl. per day, can be increased to 15,000 bbl. per day by the addition of a third filter unit. All illustrations and design data described in this article apply to the Morris system.

EXCLUSIVE In designing a salt water treating plant there is one objective toward which all processes must contribute. That objective is to produce a water that is free of oil, precipitates, and organic matter. In addition, the water must be chemically stable so that no plugging materials will develop after filtration to lower the intake capacity of the disposal well. The essential steps in achieving the objective are described as follows:

▼ **Skimming.** Removing oil from the incoming water is the first step in achieving the objective. The incoming water will always contain oil in varying amounts from a rainbow of oil to the accidental dumping of several barrels of live pipe line oil. These contingencies must be provided for and guarded against. Fig. 1 shows a line sketch of a gravitational oil skimmer. The reasoning employed in the arrangement of baffles is transferring the water that contains the least oil in one section to the succeeding section at a point occupied by the water having the highest percentage of oil in that section. In other words, water is taken from the bottom of one section and deposited into the top of the succeeding section.

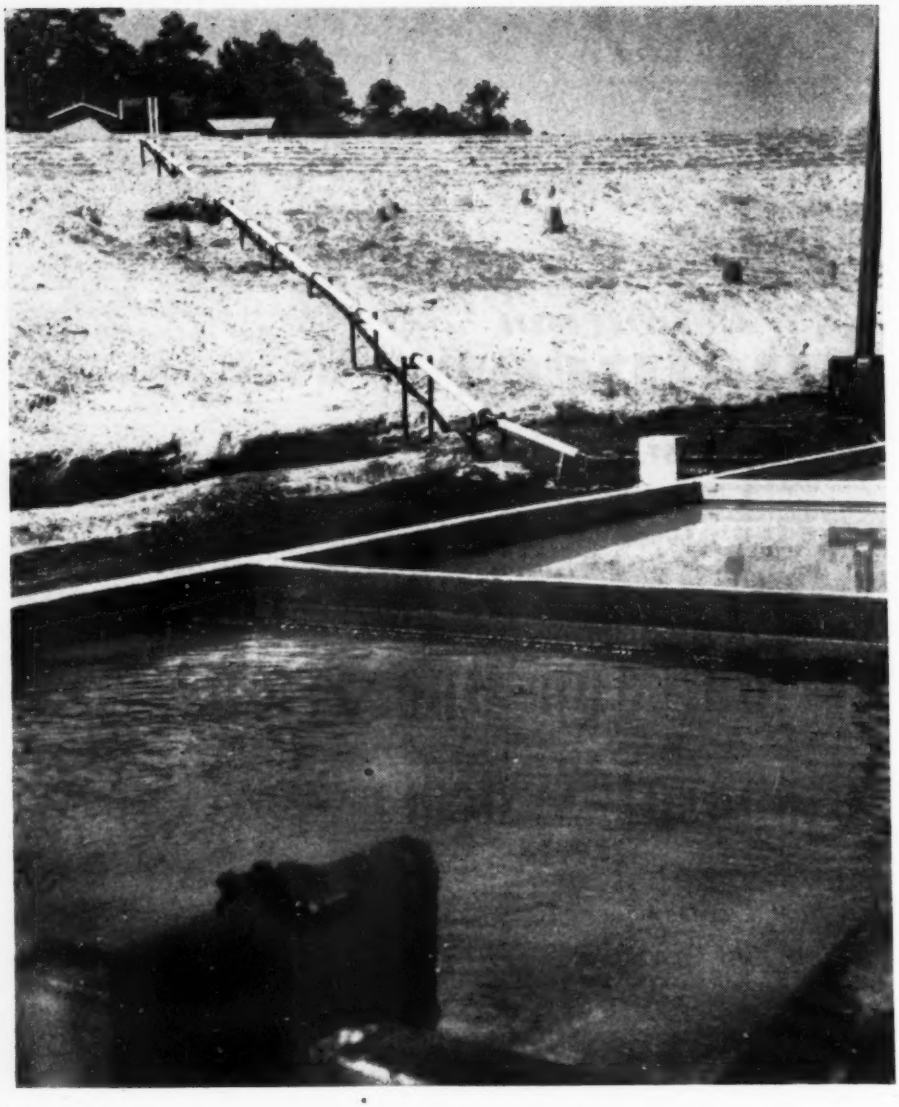
It is to be noted that each section of the skimmer is successively larger than the preceding section. This provides a longer period for separating the more reluctant oil from the water.

Finally the skimmed water is pumped to the aerating tower by means of an electric centrifugal pump operated by a float control.

The simplicity of the skimmer belies the complexity of the problem. Actually the oil is present in the water in two different physical conditions. In one form the oil occurs in bulk and as such promptly floats to the surface and may be removed by a series of baffles. Oil in such condition is troublesome and presents problems from a chemical point of view in the treating of salt water for injection.

Oil also occurs in the salt water in a second state that is of interest in a physical-chemical sense. Such oil is a finely divided suspension, which under the existing conditions is perfectly stable and will not separate. This finely divided oil

*Chief engineer, East Texas Salt Water Disposal Company.



Oil skimming pit. Water enters the system through the header in foreground, passes through pumps to aerating tower on hilltop.

suspension is of the oil-in-water type and, as such, loses the properties of the oil and appears to be like water. Such water-like properties arise from the fact that each small oil droplet has a film of water bound to its surface. This film of water, due to the electrostatic forces that hold it, is in a highly compressed state and does not have the properties usually associated with water. There is, however, a gradual transition to the ordinary kind of water as the distance from the particle of oil increases. This transition of properties causes the particle to behave as though it were water, with the result that removal by settling will not take place. Oil present in the water in such condition must be removed by chemical means as will be explained later.

▼ **Aerating.** The second step in achieving the objective is to aerate thoroughly and completely the skimmed water. Aeration of the salt water is done for three reasons, namely:

1. To remove any gases that might be in the salt water. The salt water contains a large amount of carbon dioxide, resulting from the breakdown of the bicarbonates, petroleum gases, dissolved in the water at rather high partial pressures and possibly some noxious gases, such as hydrogen sulphide, resulting from secondary reactions such as reduction of the sulphates.

2. To oxidize the iron and similar compounds from the ferrous or soluble state to the ferric or insoluble state.

3. To form aerobic conditions in the salt water in order to aid in the control of bacterial activity in the salt water.

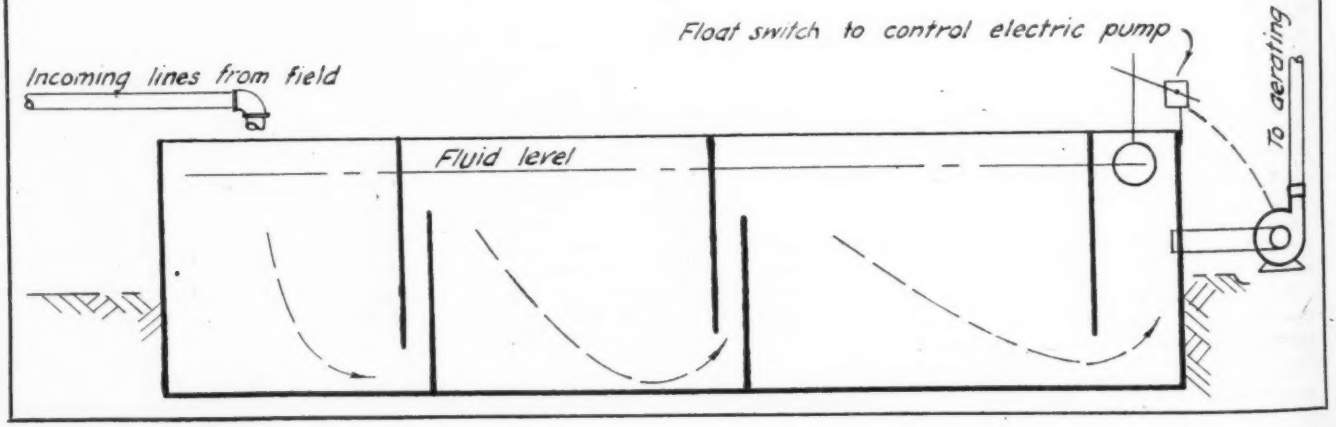
It has been mentioned in previous paragraphs that the iron and calcium are present in the water as their respective bicarbonates. These unstable compounds break down according to the following reactions:

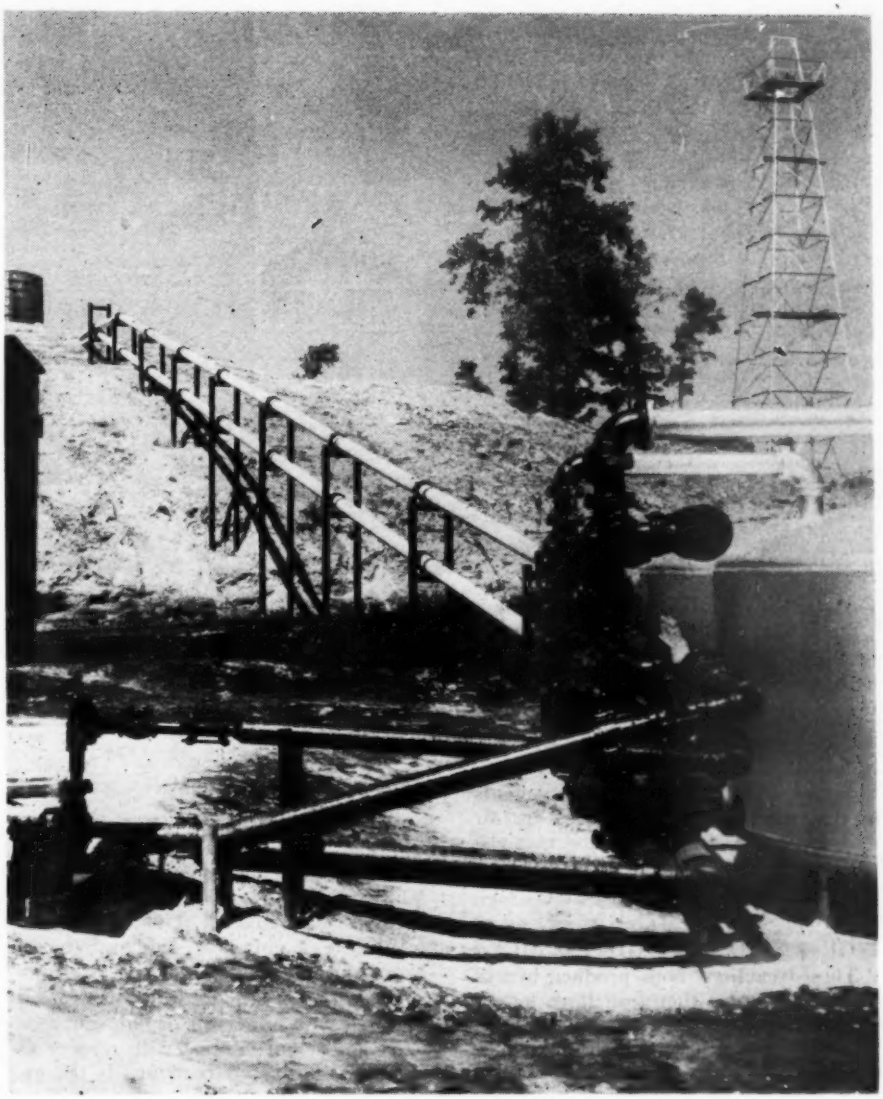
$$Ca(HCO_3)_2 \rightleftarrows CaCO_3 + H_2CO_3$$
$$Fe(HCO_3)_2 \rightleftarrows FeCO_3 + H_2CO_3$$
$$\searrow \nearrow \quad H_2O + CO_2$$

It may be seen that these bicarbonates exist in equilibrium with the carbonates and carbonic acid, which in turn is in equilibrium with water and carbon dioxide. The extent to which the equilibrium is shifted to the right or to the left is a function of the partial pressure of carbon dioxide.

In aeration the salt water containing the bicarbonate at a high partial pressure of carbon dioxide is brought into

Fig. 1. Sketch showing arrangement of baffles in oil skimming pit. Water is gathered from the various lease treating tanks by gravity. After skimming the water is pumped to the aerator tower.





Water from the treating pit passes through two 96-in. sand filters before entering the disposal well.

equilibrium with air at a low partial pressure of carbon dioxide. As a result the carbon dioxide leaves the salt water and goes into the air in an effort to equalize the partial pressure of carbon dioxide in the water and in the air. To hasten this reaction for removing the carbon dioxide the water is given a very large surface, either by spray towers or slabs or blowing air bubbles through the water. In order to make the aeration complete and remove all the carbon dioxide, it is necessary to bring a continuous supply of fresh, carbon dioxide free air in contact with the water. As aeration removes carbon dioxide, an acidic gas, this reaction tends to increase the pH of the water.

For these reasons, it is desirable that thought be given to the type of aerators to be used and the selection of the site for their construction.

A characteristic of water from the East Texas Woodbine sand is the presence of iron compounds dissolved in the ferrous state. Such a state, at the pH of salt water, is possible only when air is completely excluded from the water. As soon as air comes in contact with the salt water these ferrous compounds are oxidized to the ferric compounds, which are almost completely insoluble in salt water. Thus the aeration serves to remove the iron from the salt water. The reaction for this oxidation may be written as follows:

$$4FeCO_3 + O_2 \rightarrow 2Fe_2O_3 + 4CO_2$$

A more complete picture of the chemistry of aeration may be had from consideration of the following reaction, which includes not only the oxidation of the iron but also the breakdown of the bicarbonates as discussed previously:

$$4Fe(HCO_3)_2 + 2H_2O + O_2 \rightarrow 4Fe(OH)_3 + 8CO_2$$

As in this reaction 8 molecules of carbon dioxide are formed, any previous remarks relative to the need for continuous supply of fresh, carbon dioxide free air still are true.

Quite frequently a reaction, either bacterial or chemical, occurs in the water, which produces hydrogen sulphide by reducing the sulphates in the salt water. If and when this reaction occurs upstream, or before aeration, the hydrogen sulphide promptly reacts with the iron in the water forming iron sulphide. This is the reaction responsible for the "black water" condition sometimes encountered.

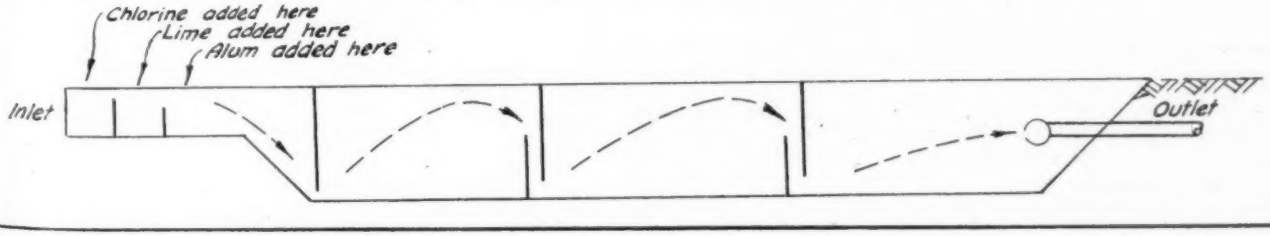
The reaction for the reduction of the sulphates present in the salt water may be written as follows:

$$Ca(SO_4) + CH_4 \rightarrow CaS + CO_2 + 2H_2O \rightarrow CaCO_3 + H_2S + H_2O$$

$$H_2S + Fe(HCO_3)_2 \rightarrow FeS + 2H_2CO_3 \rightleftarrows 2H_2O + 2CO_2$$

It may be seen that these reactions are expressed as purely chemical. It must be presumed that when conditions are right these reactions will take place by simple chemical means and cases are known where these reactions have taken place as written. It is equally well established that bacteria serve as powerful catalysts to promote chemical reactions. It would seem impossible to rule out either reaction without first obtaining more information than is now available. In any case it is the presence of hydrogen sulphide or iron sulphide that may be formed that

Fig. 2. Sketch showing arrangement of baffles in treating pit. Water enters the chlorinating pit from the aerating tower, then flows into the next pit section through a V-shaped weir, which creates turbulence to aid in mixing the lime. From this section the water flows through another V-shaped weir into the next section where alum is added. Gentle agitation of the water aids in forming the floc. Sedimentation period is from 18 to 24 hr. Outlet pipe carries the water to the sand filters.



Left: **Entrance to W. S. Morris System. Building at right houses automatic alum and lime feeders. Filter backwash tank and treating pit are in background.** ***Right:*** **Water entering the aerating tower from the oil skimming pit below. Sand filters, filter backwash pit, and oil pit at left.**

causes any difficulty from this condition.

Fortunately, these compounds are rather unstable and are readily susceptible to oxidation. The common reagents used to oxidize these sulphides are air and chlorine. The reactions may be written as follows:

$$H_2S + Cl_2 \rightarrow 2HCl + S$$

$$2FeS + 3Cl_2 \rightarrow 2FeCl_3 + 2S$$

$$FeCl_3 + 3H_2O \rightleftarrows Fe(OH)_3 + 3HCl$$

These reactions both produce hydrochloric acid and therefore have a tendency to lower the pH of the water. When the "black water" condition is oxidized with air the following reactions take place:

$$2H_2S + O_2 \rightarrow 2H_2O + 2S$$

$$4FeS + 3O_2 \rightarrow 2Fe_2O_3 + 4S$$

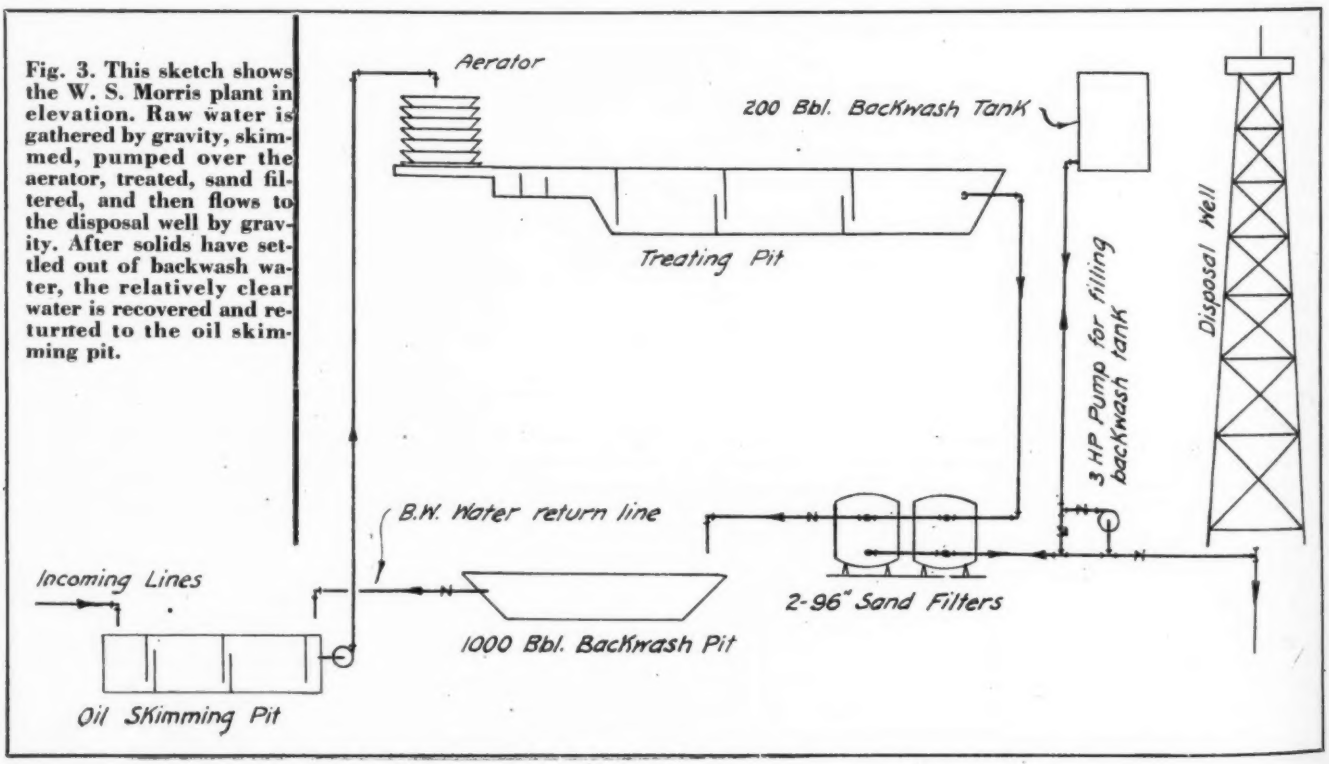
$$Fe_2O_3 + 3H_2O \rightleftarrows 2Fe(OH)_3$$

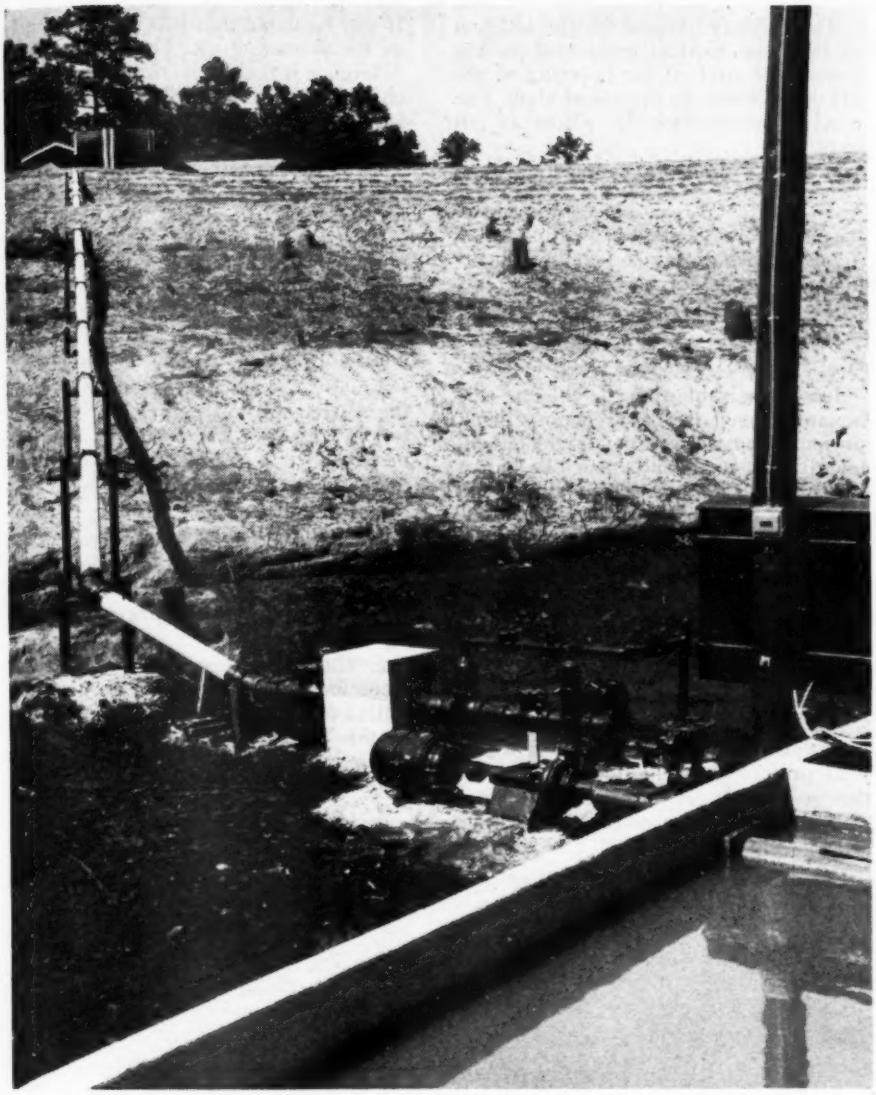
It will be noticed that these reactions produce no acidic compounds, which leaves the pH of the salt water unaffected. In both types of reactions free sulphur is produced. This sulphur is formed in a colloidal state, which accounts for the milky color the water assumes after the "black water" has been oxidized with either air or chlorine.

Of additional interest with respect to the above-discussed reactions is the effect on the future of the water if the reactions are not carried to completion and the sulphides completely removed. The presence of the sulphides render the waters, reducing and making possible the resumption of the reaction for the production of more sulphide. Such reactions would take place in the main settling pit and also downstream from the filters, which would give rise to the "black water" condition in the injection well probably to the extent that iron was present in the filtered water either through incomplete treatment or corrosion of pumps, fittings, and tubing.

Hydrogen sulphide in itself would have no ill effect on the injection well

Fig. 3. This sketch shows the W. S. Morris plant in elevation. Raw water is gathered by gravity, skimmed, pumped over the aerator, treated, sand filtered, and then flows to the disposal well by gravity. After solids have settled out of backwash water, the relatively clear water is recovered and returned to the oil skimming pit.





Pumps lifting water to the aerating tower from the oil skimming pit are controlled by float switches in the pit.

and is harmful only to the extent of the secondary reaction, which produces the metallic sulphides that are evidenced in the "black waters."

▼ **Chemical treatment. Sterlization.** The bacteria most commonly associated with salt water disposal is the anaerobic sulphate reducing type, namely, the Vibrio Desulfurican, which thrives best at temperatures of from 100° to 120°F.

The word anaerobic means "without air," which means that in order to thrive the bacteria must not be exposed to oxygen or, chemically speaking, must be maintained in a reducing environment. It becomes clear that by the introduction of an oxidizing substance, such as chlorine, the reducing environment is changed to one of an oxidizing character. This change is the major role played by chlorine when considered as bacterial control only. Chlorine is toxic to most bacteria in itself, however, and this property plays a secondary role in treating salt water.

Salt water as produced has the reducing properties necessary for maintaining bacterial growth. Enough chlorine must be added to destroy this reducing power and also give the water an oxidizing power of its own in order to prevent future growth of bacteria.

▼ **Coagulation and settling.** With the use of the rapid sand filter the need for introducing a reasonably clear water becomes evident. If too much foreign matter of extremely small particle size must be removed from the waters, the pressure drop becomes excessive and inefficient filter operation results. The use of coagulants became widespread in order to prepare properly the water for filtration through the rapid sand filter.

In nature most colloidal particles possess a negative electrostatic charge, which causes such particles to remain in stable suspension indefinitely. This is true of the oil droplets of the oil-in-water variety that we have previously said must be removed by chemical means. One of the easiest and best ways to neutralize the negative charge is to form a positively charged colloidal particle in the water. In forming the floc, by the addition of alum, a positive charge is created on the particle so formed. As the result of the attraction of the two oppositely charged particles collisions between them occur causing a mutual discharge, or neutralization, of both particles. By a succession of such collisions and by mechanical contacts the particles grow to such size they begin to settle. The choice of an aluminum salt for this purpose is particularly fortunate because the trivalent aluminum ion is very effective in destroying the electrical charge on the oil droplet.

If a particle similar to a wad of pine needles can be visualized some idea of the structure of these electrically neutral particles can be had. As such a mass comes in contact, on settling through the water, with another similar mass, the two intertwine and are held together mechanically.

If the two states of the particle are kept in mind the physics, or mechanical control, of flow velocities can be understood. Although the water contains a relatively large number of electrically opposite charged particles, a rapid current increases the chances of the particles to collide and neutralize each other. As soon as the electrical properties have been destroyed and the mechanical phase of coagulation becomes dominant, it is desirable to decrease the rate of flow of the water. Although motion increases the chances for collision, too rapid movement causes the particles, or floc, to break up. A properly designed system provides for suitable fluid velocities in order to coagulate completely and settle the water. Obviously the design of the system must provide for thorough mixing of the coagulating materials with the water prior to flocculation and settling.

In the choice of alum, (aluminum sulphate), consideration was given not only to the charge on the colloidal particles but also to its reactions with the salt water and the constituents in the water. Two basic reactions between the salt

Survey indicates lower postwar demand for gasoline

Early postwar gasoline demand will be about 75 per cent of prewar requirements, according to a survey by A. H. Adams and B. H. Bell of Gulf Research and Development Company in a publication of the American Chemical Society. Rapid recovery to or above normal prewar use is expected to follow as new tires and cars come into production.

It is believed that all cars capable of operation at the end of the war can be put on the road within one year, but with limited production, it will take 2 years or more to replace cars worn out during the war period. Some military and increased commercial and farm use of gasoline will be important in the immediate postwar period, but the most significant factor influencing the postwar market will be the number of cars still operating.

"In general," said the report, "prospects for gasoline markets are not particularly dark, even in the immediate postwar period; in the subsequent period of anticipated prosperity, the outlook seems to be good indeed."

water and the alum are of interest. First is a reaction with the alkalinity of the water as illustrated by the reaction:

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 \rightarrow 2Al(HCO_3)_3 + 3CaSO_4$$
$$\uparrow\downarrow$$
$$Al(OH)_3 + 3CO_2$$

In other words, the alum reacts with any unstable bicarbonates and converts them to the stable sulphate. It is in turn hydrolyzed to aluminum hydroxide, the floc, and carbon dioxide. The aluminum bicarbonate break-down is an equilibrium reaction and might not be complete toward the aluminum hydroxide, which might permit a small quantity of aluminum to pass through the filters and be hydrolyzed in the well bore. Small amounts of aluminum have, in fact, been found at the bottom of injection wells.

The second, and by far the most important, reaction between aluminum sulphate and the salt water is a straightforward hydrolysis reaction as follows:

$$Al_2(SO_4)_3 + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2SO_4$$

In this reaction it will be noticed that three molecules of sulphuric acid are produced for each molecule of alum used. The formation of this acid lowers the pH of the water and represses the hydrolysis reaction. At pH values below 5 or 6 the alum is soluble in the salt water without forming the floc.

The primary purpose for the addition of lime, an alkaline compound, to the water is to prevent the lowering of the pH of the water by the use of alum. The reaction to increase the pH is as follows:

$$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2H_2O$$

An additional reaction resulting from the use of lime (calcium hydroxide) is in neutralizing any remaining bicarbonates that might be present. For example:

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$$

It is conceivable that the calcium carbonate formed by this reaction, being present in small amounts, might be colloidally suspended and as such be stable. Stirring with solid $CaCO_3$ would tend to coagulate the particles of calcium carbonate, giving the appearance of a calcium carbonate supersaturation. Passing the water containing a stable suspension of calcium carbonate through a filter would tend to flocculate the solid, which would adhere to the pores in the sand causing the calcium carbonate cementation often encountered in filters after long periods of operation. It would appear preferable to stabilize completely the carbonates in the aeration steps rather than precipitate them with lime after flocculation.

Fig. 2 is a sketch of the settling pit. It will be noted that it is just as simple as the skimming pit. The fundamental difference is that in the skimming pit the object is to bring the floating oil to the surface and in the settling pit the object is to take the floc to the bottom. The baffles are therefore arranged so that the water that is most free of floc in one compartment is introduced into the succeeding compartment at a point occupied by the water containing the greatest concentration of floc in that compartment. In other words, water from the top of one section flows into the bottom of the succeeding section.

Finally, the clarified water flows from the settling pit to the pressure sand filters by gravity, thence through a master meter and into the disposal well.

The drilling and completion of the disposal well was more or less routine, the procedure having been as follows*:

1. The surface hole was drilled to approximately 110 ft. at which depth 10¾-in. casing was set and cemented with 150 sacks of cement.

2. The cement was allowed to set a minimum of 24 hr. and a 9⅞-in. hole was drilled to the top of the Woodbine sand. At this point the diameter of the hole was reduced to 6¼ in. and the hole was drilled to the base of the sand.

3. The casing seat was selected after an electric log was run to determine the base of the first shale break below subsea depth of 3320 ft., the original oil-water interface.

4. Seven-inch casing was then run to the casing seat and cemented with 150 sacks. An official Railroad Commission test was then made after the cement was allowed to set a minimum of 48 hr.

5. After a satisfactory test, the plug was drilled and the 6¼-in. hole was underreamed from the casing seat to the total depth of the well to 8 in. dia.

6. The well was then flowed by gas lift until it was thoroughly cleaned.

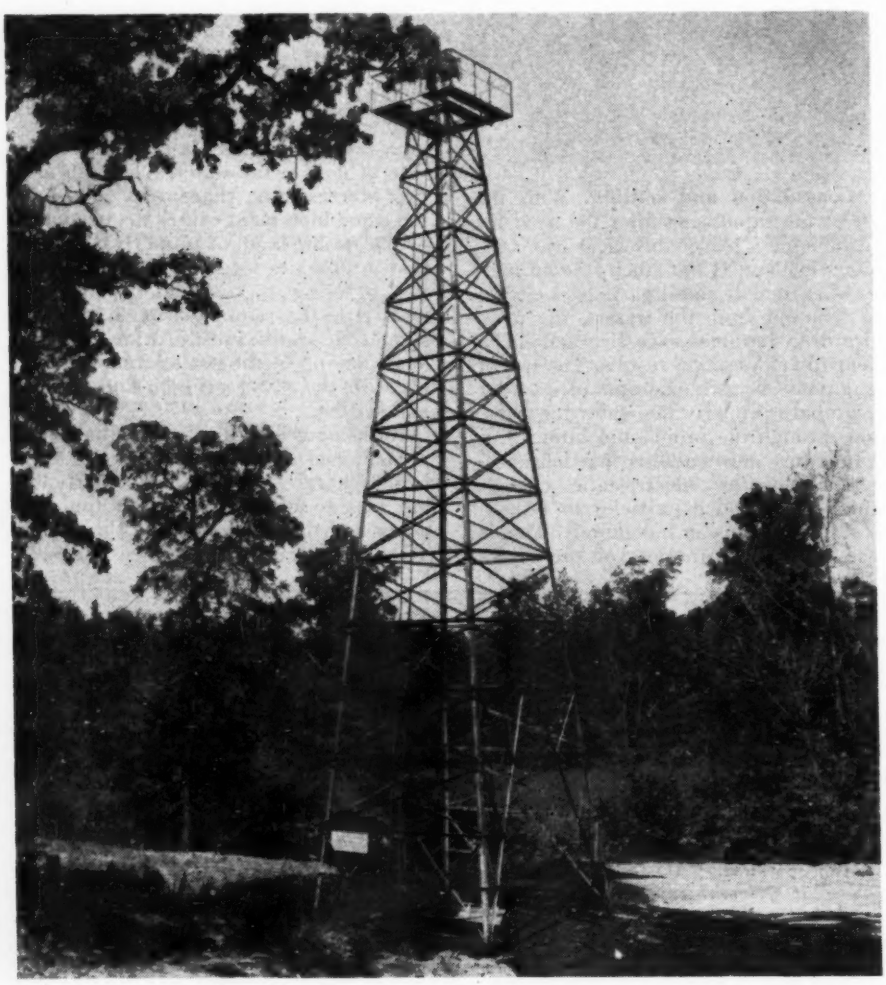
7. Cement lined tubing 5½ in. in diameter and equipped with a hookwall packer was run in the hole and the packer was set as near the bottom of the 7-in. casing as was practical. The well was then ready to receive the water from the filters.

The intake capacity of the Morris well is not known but on a test of several hours it took water by gravity at the rate of 10,000 bbl. per day with full vacuum on the wellhead. The testing rate was limited only by the capacity of the two sand filters.

▼ **Acknowledgment.** The author acknowledges with thanks the helpful ideas contributed by the staff of the East Texas Salt Water Disposal Company and also by Dr. G. G. Wrightsman of the Humble Oil and Refining Company.

*See *The Petroleum Engineer*, November, 1943, page 61.

★ ★ ★



W. S. Morris system disposal well. Water flows into the well by gravity from the sand filters.

DEEP WELL COMPLETION INVOLVES WATER SHUTOFF

Cottingham No. 1, McClarn County, Oklahoma, completed in Wilcox sand from 10,625-45 ft.

By C. C. PRYOR

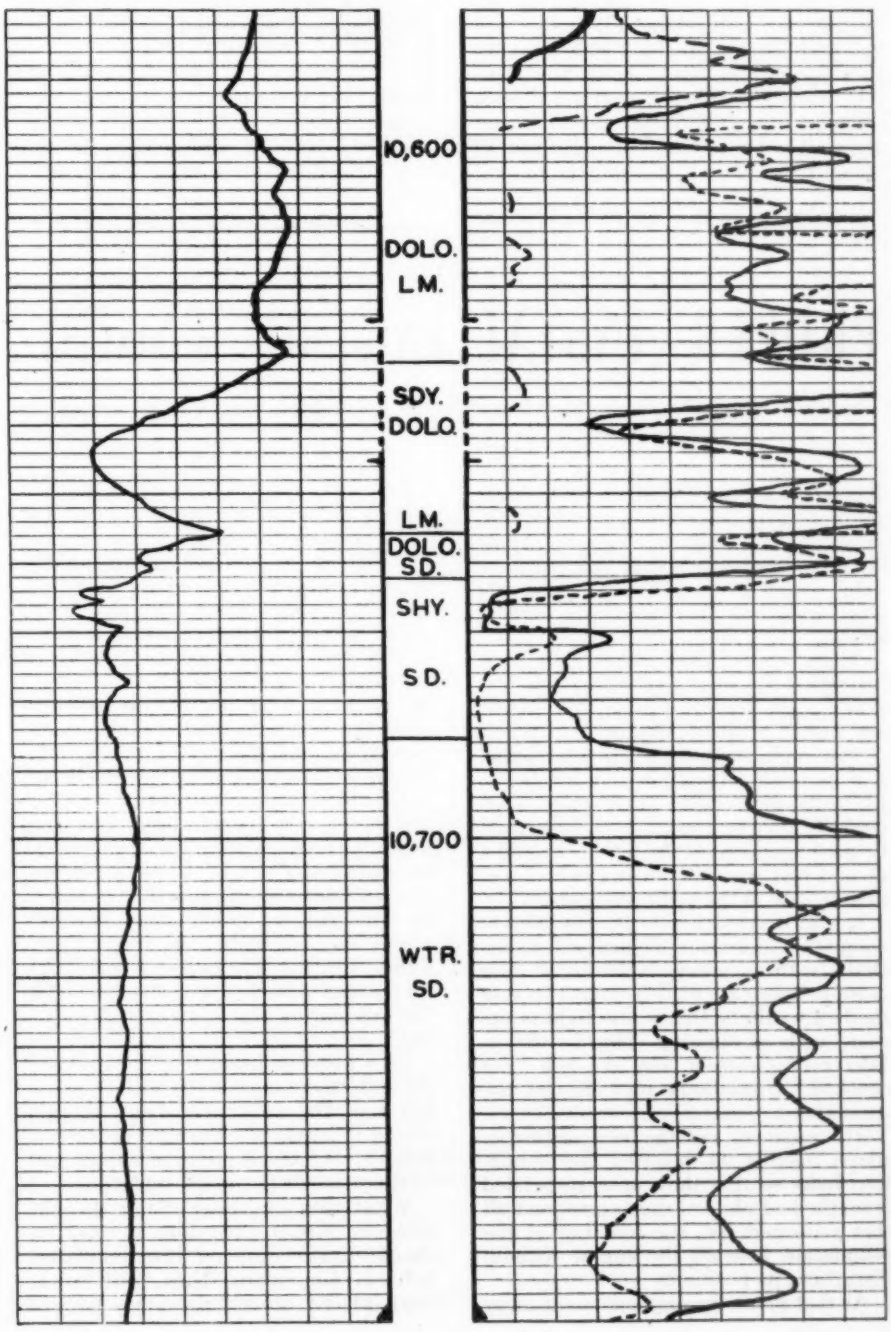
EXCLUSIVE Oil well completion practices have progressed in step with developments in other branches of the petroleum industry; as a result wells are seldom abandoned before being thoroughly tested for possible production. One of the major reasons for the abandonment of wells is the encroachment of salt water into the well bore. Large volumes of water in flowing or pumping wells generally shorten the producing life of the oil well and increase the cost of production. New methods, equipment, and materials have aided greatly in overcoming this problem. Wells producing over a period of time in water drive fields from depths too near the oil-water interface and in thin sand sections are susceptible to connate water intrusion. In individual fields completion practices have been developed and usually apply to all the wells producing under similar conditions in the field.

Deep discovery wells in new pools present one of the most difficult completion problems when salt water is encountered. Operators make use of well logs, gun perforating, and squeeze cementing to eliminate water production, and although this equipment and methods are regarded as standard, a careful study of conditions is necessary for successful application. The completion described in the following paragraphs is typical of the problems faced by operators in successfully completing deep wells. Deep well drilling costs at the present time prohibit any but the most searching and exhaustive efforts to obtain production from the well.

The Carter Oil Company well, Cottingham No. 1, C SE SW 4-7-3w, in the Anadarko Basin west of the Nemaha Ridge, McClain County, Oklahoma, was drilled to a total depth of 11,209 ft. by an Olson Drilling Company rig powered by three heavy-duty engines, using butane as fuel, compounded to handle the loads involved in drilling with 3-in. pipe. A log run before the well was cased and correlated with cores indicated that production could be had from 10,625 ft. to 10,645 ft. in the second Wilcox sand. Operators ran 957 ft. of 13⅜-in. surface casing cemented with 1000 sacks, cemented 9⅝-in. protection pipe at 6474 ft. with 450 sacks, and 5½-in. casing to 10,769 ft. with 350 sacks. The pipe was perforated from 10,625 ft. to 10,640 ft. with 60 holes.

A drillstem test from 10,585 ft. to 10,640 ft., opened for three hours, recovered 8849 ft. of mud. With the packer reset at 10,585 ft. the well flowed 6 bbl. of fluid per hour, 10 per cent mud, through a 1¼-in. top choke and ½-in. bottom choke. Additional perforations were made from 10,640 ft. to 10,650 ft. with 40 shots. With the packer set at 10,579 ft. the well made 469 bbl. of oil and 301 bbl. of water in 23 hrs. A later 25-hr. test through a ⅛-in. choke, showed the well to be making 111 bbl. of oil and 102 bbl. of water. As subsequent testing showed the well to be making too much water for commercial production, all perforations were squeezed with 150 sacks cement from 10,625 ft. to 10,650 ft. and the well opened up. The cement evidently did not set in the oil portion of the sand and the well flowed 379 bbl. of oil and 8 bbl. of water through chokes ranging from 1/16-in. to 1-in.

Tubing pressures ranged from 300 lb. per sq. in to 400 lb. per sq. in. with the well making from 15,000 to 43,000 cu. ft. of gas per day. A later production test showed 345 bbl. of oil plus 41½ bbl. of water through 1/16-in. to ¼-in. choke. On another test the well made 489 bbl. of oil and 96 bbl. of water and mud through the same size chokes, with 400



Schlumberger log of Cottingham No. 1. Water was believed flowing from last 5 ft. of sand.

lb. per sq. in. tubing pressure. Tested two days later the well made 396 bbl. of oil and 24 bbl. of water through a 1/16 in. choke. Twenty-four hours later the well produced 368 bbl. of oil and 24 bbl. of water.

CORING RECORD

Core depth, ft.		Footage recovered, ft.-in.	Footage cored, ft.-in.
8,848	52	4 — 0	4 — 9
8,852	61	9 — 0	8 — 1½
9,441	48	7 — 0	4 — 6
9,716	24½	8 — 6	1 — 0
9,724½	39	14 — 6	3 — 0
9,918	26½	8 — 6	4 — 6
10,630	36	6 — 0	5 — 10
10,636	41	5 — 0	5 — 0
10,641	45½	4 — 6	1 — 6
10,645½	47	1 — 6	0 — 6
10,652	56	4 — 0	2 — 10
10,656	65	9 — 0	3 — 6
10,670	81	11 — 0	9 — 0
10,681	88	7 — 0	4 — 6
10,688	92½	4 — 6	4 — 6
11,155	60½	5 — 6	5 — 6
Total		109 — 6	69 — 2½

Believing that the well was producing water from the lower five feet of the Wilcox, the well tubing was pulled and the perforations squeezed with 76 sacks of cement from 10,625 ft. to 10,650 ft. The casing was again perforated with 40 holes from 10,635 ft. to 10,645 ft., but the well failed to flow. An additional 40 shots were placed in the section and packer set for a test, however, the well would not flow and no fluid could be swabbed. A third perforating gun was run and 52 shots used in the section from 10,625 ft. to 10,635 ft. and 63 holes shot from 10,635 ft. to 10,645 ft. Tubing was then run with packer and a testing tool on bottom.

When the well was opened for 22 hr. it flowed 464 bbl. of oil plus 13 bbl. of mud and water through a ½-in. choke. Later tests showed the well to be making 20 to 35 bbl. of oil per hour, without water, through chokes ranging from 3/16-in. to 5/32-in. The well was completed for a production of 322 bbl. per day of 41-gravity oil from the 115 perforations just described with approximately 250,000 cu. ft. of gas.

Production from the Cottingham No. 1 is being transported by tank truck to the loading rack at Purcell, Oklahoma, on the Santa Fe railroad line, loaded into tank cars, and shipped direct to the Imperial Oils, Ltd. refinery at Regina, Saskatchewan, Canada. The pool opened by the well has been named the Washington. Imperial Oils, Ltd., Canadian subsidiary of the Standard Oil Company of New Jersey, and the unit selected by Lieut. Gen. Somervell, U.S.A., to build the Canol project, has contracted to take all the high gravity crude the Carter Oil Company produces in the new pool. Other wells are being drilled in the pool. ★ ★ ★

Dressed Up and Going Places

The Petroleum Engineer has a new tailoring job. It has discarded its old suit of type for a new style selected for easy reading and wartime conservation of paper.

An estimated 20 to 25 per cent of space is saved by using the new typography. This space is now devoted to the interest of the reader in the form of additional editorial matter that can be carried without requiring additional paper, a vital war material at this time.

The new type is condensed without losing its high legibility that permits comfortable reading.

P 090.

PROPER INSTALLING OF ENGINE ON FOUNDATION

By W. F. SCHAPHORST

In this brief discussion are some facts pertaining to an engine erection, witnessed by the writer, which he thinks contains information that may prove of value—what to do and what not to do when installing an engine on a foundation.

There was an old engine of 50 hp., belt connected to overhead shafting. The engineer's job was to remove that engine and install a 100-hp. engine in its place.

The engineer removed the old engine and its brick foundation and decided to place the new engine in its place so accurately that the same drive belt could be used from one of the flywheels, and a second belt from the other flywheel was to take care of the additional power.

It was necessary for the engineer to compute the center distance between shafts with accuracy, including a little more to take care of belt stretch so that the belt would be sufficiently tight to operate without slipping. This he did as later events proved, but, the belt "ran crooked." Somebody had slipped up, somewhere.

The engineer put the new engine in place, lined it up, inserted the foundation bolts so that they were suspended from the bed plate of the engine, and all that remained was the building of the foundation beneath the engine without disturbing its position.

At that point the engineer went away on vacation. He had made arrangements with a contracting company to do the foundation work during his absence, and of course he told the contractor that the engine must not be moved the least fraction of an inch from the position in which it was placed by the engineer.

When the engineer returned he found the foundation completed. It "looked" fine, but when he put on the belt and gave the engine a trial the abovementioned sad fact became apparent—the engine was not properly aligned and the only way in which it could be rectified was to remove enough brick from beneath the engine so that the engine could be given a slight twist. It was an expensive job, but the engineer felt it had to be done and he had it done. The belt would have operated in its crooked condition, yes, but this engineer didn't relish the idea of having such a hodge podge belt job staring him in the face day after day.

This writer believes that the engineer did have the engine in its proper place, but that the contractor unwittingly moved it during the bricking process. It doesn't take much pulley misalignment to cause a belt to run off center.

What this engineer didn't do—the thing he *should* have done is this: He should have centered the foundation bolts in 4-in. pipes. Then, with brickwork placed around the pipes he still would have had ample space for adjustment without removing any of the foundation.

Then, after being sure of the alignment, grout or melted lead should have been poured into the pipes to guard against possible shifting of the engine due to belt pull or other external force.

In preparing the grout, it is essential to make it thin enough so that it will flow readily, at the same time it should not be made "too thin." Use one part high grade cement and three parts sand and then just enough water to permit positive flow so that the openings will be entirely filled. The best proportion is 0.4 lb. of water per pound of cement of high grade. That amount of water gives a high grade cement greater strength, but the grout does not always flow as well as it should, in which event more water must be used. If the amount of water is increased to 0.5 lb. per pound of cement the compressive strength of the cement is reduced 37 per cent. If the amount of water is increased to 0.8 lb. of water per pound of cement the compressive strength is reduced 71 per cent. It is evident, therefore, that the percentage of water in the grout is important.

If molten lead is poured into the pipes be certain that there is no moisture in the pipes, and pour quickly. Also, prepare enough molten metal so that the hole can be filled in one pouring. ★ ★ ★

CORROSION IN GAS AND CONDENSATE WELLS IN THE KATY FIELD OF TEXAS*

By F. W. JESSEN†

Introduction—purpose of this investigation. Severe corrosion of equipment in wells producing gas or hydrocarbon condensate has focused attention once again on the problem existing potentially everywhere that metals are exposed in process industries. Certain well known fundamental chemical reactions, based on the electrochemical theory of corrosion, are generally accepted as explaining satisfactorily the mechanics by which metals pass into solution—corrode. As under any given set of conditions certain variables are present the corrosion encountered must be explained by accounting individually for each of such variables or collectively by grouping two or more of the factors. It is the purpose of this investigation (1) to determine, with the limited data obtainable, the possible cause of the corrosion noted in high pressure gas and condensate wells, (2) to point out a probable mechanism whereby this corrosion takes place, and (3) to suggest factors to be studied in a laboratory investigation of the problem designed to ascertain the mode of attack of the metal by the corrosive media. Certainly, no judicious choice of corrosion resisting materials, metal alloys for example, or proper treatment with chemicals to decrease the corrosivity, may be adopted without some knowledge of the basic cause of corrosion.

Previous investigation. Apparently little cognizance has been given to the possibility of corrosive action on metals in gas or gas-condensate wells as evidenced by the dearth of previous information on the subject. Furthermore, the criteria for establishing whether or not corrosive action occurred may have easily been overlooked; however, recent failures of well equipment has aroused the intense interest of several investigators and has shown the imperative need for a critical examination of conditions under which corrosion of the metal developed and progressed before any measures could be instituted to inhibit the deleterious action.

The recent work of Bacon and Brown[1] in reporting the corrosion experienced in wells at the Opelika field in Henderson County, Texas, seemingly showed little correlation between the many factors considered. Undoubtedly, numerous cases of a like nature have occurred elsewhere. Perhaps no ready plausible explanation of the corrosion phenomena presented itself, or lack of time prevented further study.

Results of present investigation. The compilation of data obtained during the last 3 months at the Katy field in Harris and Waller counties has been made available for this study and is presented in Table 1. These data were accumulated over a period of several months, though not until January, 1944, was an attempt made to obtain data in a fixed, routine manner. Meager information concerning many of the factors that may contribute to the overall effect of corrosion is available in most instances. However, in two cases, namely, wells K.F.G.U. 9 and K.F.G.U. 19, there seem to be a sufficient number of samples to justify some postulation on the mechanism of corrosion. Even of the data available from these two wells, however, that from K.F.G.U. 19 may not be too reliable because this is a dual completion well and the exact source of water, originating either from the tubing or casing, is unknown.

The following factors appear to be of prime importance, though it is recognized that others may be of secondary value: (1) daily average production rate of gas, hydrocarbon condensate, and water, (2) reservoir temperature and pressure, (3) wellhead flowing temperature and pressure, (4) wellhead shut-in temperature and pressure, (5) composition of gas, and (6) composition of produced or condensed water. Other factors that may possibly contribute to the corrosion are variations in the metal, such as slag inclusion, stress and chemical impurities; and certain electrical effects, as streaming potentials and stray current electrolysis. The present discussion, however, is limited to the former variables though a comprehensive study of all factors may be necessary before complete solution of the problem is obtained.

Table 1 shows the well from which samples were obtained, date, production rate of gas, operating temperature, pressure and temperature of the portable field separator, and the analysis of the water condensed while the well was producing at the rate indicated. In addition, the column "water-gas ratio" gives the amount of water condensed when the indicated volume of gas was passed through an experimental portable separator operated at the temperature and pressure shown.

The portable separator was placed so as to obtain a sample from the flow line from the well immediately downstream from the wellhead, the pressure being maintained at the pressure prevailing at the plant, that is, 1850 lb. per sq. in. Likewise, the temperature was kept fairly constant at 85 to 90° F. Fig. 1 shows the relative position of the separator, wellhead equipment, field lines, and plant. Gas was withdrawn from the

*Presented before National Association of Corrosion Engineers, Houston, Texas, April 10, 1944.
†Humble Oil and Refining Company.

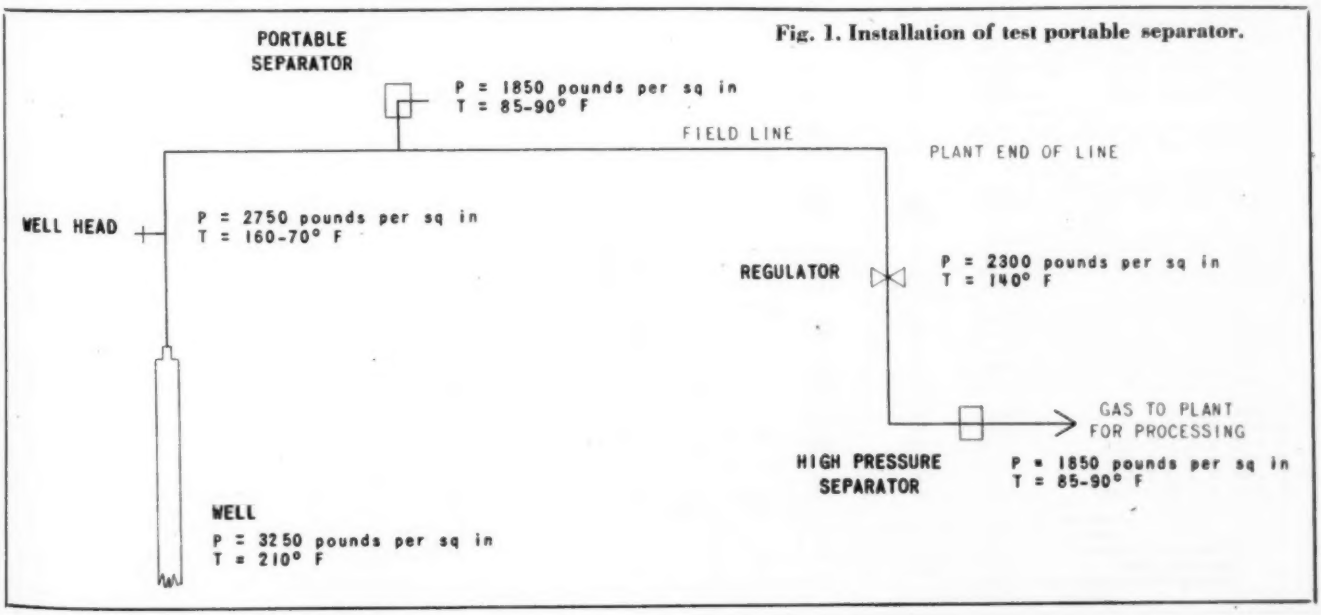

PORTABLE SEPARATOR
P = 1850 pounds per sq in
T = 85-90° F
FIELD LINE
PLANT END OF LINE
WELL HEAD
P = 2750 pounds per sq in
T = 160-70° F
REGULATOR
P = 2300 pounds per sq in
T = 140° F
GAS TO PLANT FOR PROCESSING
HIGH PRESSURE SEPARATOR
P = 1850 pounds per sq in
T = 85-90° F
WELL
P = 3250 pounds per sq in
T = 210° F

Fig. 1. Installation of test portable separator.

field line near the wellhead, and sampling was done at the side of the line. Although it was recognized that this manner of sampling would not yield entirely representative volumes of gas and water, it was thought that over a sufficiently long period numerous samples removed in the identical manner would indicate relative changes in water volumes, chemical composition of the water, pH, etc.

From a laboratory analysis of the water, which contains the corrosion products as well as the elements of the corroding medium itself, the flow rate of the wells, and an estimation of the ratio of hydrocarbon condensate to water production, it appeared possible to explain some of the findings that are tabulated in Table 1.

If it is postulated that the corrosion is due to the action of carbon dioxide under pressure in the presence of water, which action was found by Miller and Heneska[9] to dissolve iron and produce ferrous bicarbonate, though rate of solution was decreased as the bicarbonate concentration increased, it follows that (1) the rate of deposition of water either in the form of droplets or continuous film influences the corrosion, (2) the per cent carbon dioxide present in the gas enhances the rate of absorption of carbon dioxide by condensed water, (3) the linear velocity of gas controls the absorption rate or replacement of carbon dioxide resulting from exhaustion of the same in the liquid phase through the reaction to form ferrous bicarbonate, (4) the reaction rate should be decreased as corrosion products accumulate provided gas velocity allows continuity of liquid film, and (5) the higher the ratio of hydrocarbon condensate to water condensed the lower should be the corrosive action; that is, in the complete absence of water, the rate of corrosion is assumed to be extremely low.

The question of what factor or factors actually control the corrosion rate of the iron may be summarized in a consideration of various interdependent rates, which are given in Table 2. The dependency of variables related to each of the individual rates shown is not confined arbitrarily to that particular process but may be influenced by other reactions. For example, the rate of reaction of carbonic acid with iron will be dependent on the amount of carbon dioxide absorbed by the water film as well as by the removal of reaction products. However, under certain fixed or controlled conditions of temperature, pressure, and composition of the gas the overall corrosive action resulting in the solution of iron may be evaluated in terms of only three variables, (1) the rate of flow, (2) amount of water produced or condensed, and (3) the amount of hydrocarbon liquid condensate present.

The absorption of carbon dioxide by water droplets and thin films has been studied by numerous investigators[2, 4, 5, 6, 13, 15]. The effects of pressure and temperature on the solubility of carbon dioxide in water have been investigated by Steenhoff and Möller[16], Wiebe and co-workers[17, 18], and Katz[7] while Shen-Wu Wan and Dodge[14] reported results on solubility of carbon dioxide in benzene at elevated pressure.

The hydrogen ion concentration, the equivalent amounts of bicarbonate ion formed, and the dissolved carbon dioxide that exists when carbon dioxide is dissolved in water were found by several investigators[3, 10, 12] to be related to pressure, the hydrogen ion concentration being calculable from a consideration of the equilibrium constant and the pressure.

An examination of the data of Table 1, plotted in Fig. 2, for well K.F.G.U. 9 which, incidentally, is the only system from which representative data extending over a period of 2 months is available, shows some rather interesting points.

Before considering the curves of Fig. 2, it seems appropriate to study the relative amounts of water present in the gas produced from the wells at Katy. The results of a study of the methane-water system by Olds, Sage, and Lacey[11] indicate that the moisture content of saturated gas of approximately the same composition as that at Katy at a reservoir pressure of 3250 lb. per sq. in. and temperature of 210°F. is 40 gal. per million cubic feet. At a pressure of 2500 lb. per sq. in. and a temperature of 170°F., the saturation is 20 gal. per mil-

TABLE 1
Summary of data from wells
Katy Field, Texas, July, 1943 - April, 1944

Date	Well number or source of sample	Production rate, M. cu. ft.	Portable field separator: Temperature, °F.	Portable field separator: Pressure, lb. per sq. in.	Total fluid produced, gal. per day	Water-gas ratio determined by portable field separator	pH	Analysis of condensed water (ppm): Carbon dioxide	Bicarbonate	Chloride	Iron	Remarks
7-21-43	Highpressure separator	..	..	..	6,000	....	6.0	..	299	None	247	Oxygen none.
8-11-43	Highpressure separator	..	..	..	6,000	....	5.8	97	275	None	197	.....
12-22-43	Highpressure separator	..	..	..	10,000	....	6.2	27	372	None	600	.....
8- 4-43	K. F. G. U. 4	18,700	89	1800	..	....	4.9	19	..	..	127	¶Down-stream from choke
8- 4-43	K. F. G. U. 4	..	105	1800	..	....	5.2	13	..	..	92	¶Upstream from choke.
2- 1-44	K. F. G. U. 4	21,000	90	1850	..	....	6.3	194	97	16	142	.....
8-11-43	K. F. G. U. 19	27,500	88	1800	..	....	5.4	77	..	50	251	Upstream from choke.
8-11-43	K. F. G. U. 19	..	88	1800	..	....	5.2	90	..	45	178	Down-stream from choke.
1-29-44	K. F. G. U. 19	9,000	..	..	..	....	6.0	107	..	25	33	.....
2-24-44	K. F. G. U. 19	16,200	..	..	..	2 cc. per 54 cu. ft.	6.4	None	49	174	540	Casing and tubing open.
3- 3-44	K. F. G. U. 19	15,400	..	..	..	2 cc. per 100 cu. ft.	6.5	None	50	16	227	Casing and tubing open.
3-13-44	K. F. G. U. 19	15,600	92	1850	..	3 cc. per 120 cu. ft.	5.8	None	134	None	192	Tubing flowing.
3-17-44	K. F. G. U 19	15,700	88	1850	..	5 cc. per 17 cu. ft.	5.5	None	49	22	156	.....
3-24-44	K. F. G. U. 19	20,800	82	1850	..	14 cc. per 14 cu. ft.	5.5	151	183	52	21	.....
8-24-43	K. F. G. U. 16	25,400	88	1800	..	....	5.5	..	..	30	200	Upstream from choke.
2- 2-44	K. F. G. U. 16	21,000	85	1850	..	....	6.4	14	110	28	185	.....
9-13-43	K. F. G. U. 9	..	..	..	..	....	6.1	None	..	None	64	Downstream from choke.
1-31-44	K. F. G. U. 9	22,200	90	1850	..	15 cc. per 15 cu. ft.	6.0	84	..	20	220	.....
2-24-44	K. F. G. U. 9	12,800	90	1850	..	11.0 cc. per 19.5 cu. ft.	6.2	None	122	194	199	Casing flowing—tubing shut-in.
3- 2-44	K. F. G. U. 9	15,900	..	..	..	11.0 cc. per 19.0 cu. ft.	6.4	None	110	26	213	Tubing shut-in.
3- 9-44	K. F. G. U. 9	20,100	..	..	..	11 cc. per 22.5 cu. ft.	6.5	85	122	12	256	.....
3-16-44	K. F. G. U. 9	21,400	88	1850	..	7 cc. per 25 cu. ft.	6.3	None	71	None	305	Tubing flowing.
3-26-44	K. F. G. U. 9	26,200	80	1850	..	7 cc. per 23 cu. ft.	5.0	75	134	42	107	.....
1-31-44	K. F. G. U. 7	23,700	90	1850	..	19 cc. per 11 cu. ft.	5.8	163	..	20	69	.....
1-31-44	K. F. G. U. 8	18,900	90	1850	..	18 cc. per 10 cu. ft.	6.0	21	..	15	160	.....
1-29-44	K. F. G. U. 3	..	..	..	..	....	6.0	65	..	128	0.7	.....
2- 1-44	K. F. G. U. 5	20,000	90	1850	..	....	6.4	101	122	38	263	.....
1-31-44	K. F. G. U. 22	30,000	92	1850	..	....	..	146	305	66	121	.....
2- 2-44	K. F. G. U. 18	15,000	90	1850	..	....	5.3	11	110	82	71	.....
2- 3-44	K. F. G. U. 11	12,000	90	1850	..	....	6.5	None	97	32	291	.....
2- 4-44	K. F. G. U. 12	17,000	90	1850	..	....	6.6	None	366	20	263	.....
2- 4-44	K. F. G. U. 13	17,000	90	1850	..	....	..	None	97	34	270	.....
2- 4-44	K. F. G. U. 3-2	20,000	90	1850	..	....	6.4	87	220	378	85	.....
2- 4-44	K. F. G. U. 16-2	10,000	90	1850	..	....	6.5	None	73	58	341	.....

Shut-in wellhead temperature—depends on length of time shut in.
pressure —2750 lb. per sq. in.
Reservoir temperature —210 °F.
Reservoir pressure —3250 lb. per sq. in.
Flowing wellbead temperature—160–70 °F.
pressure —2500 lb. per sq. in.

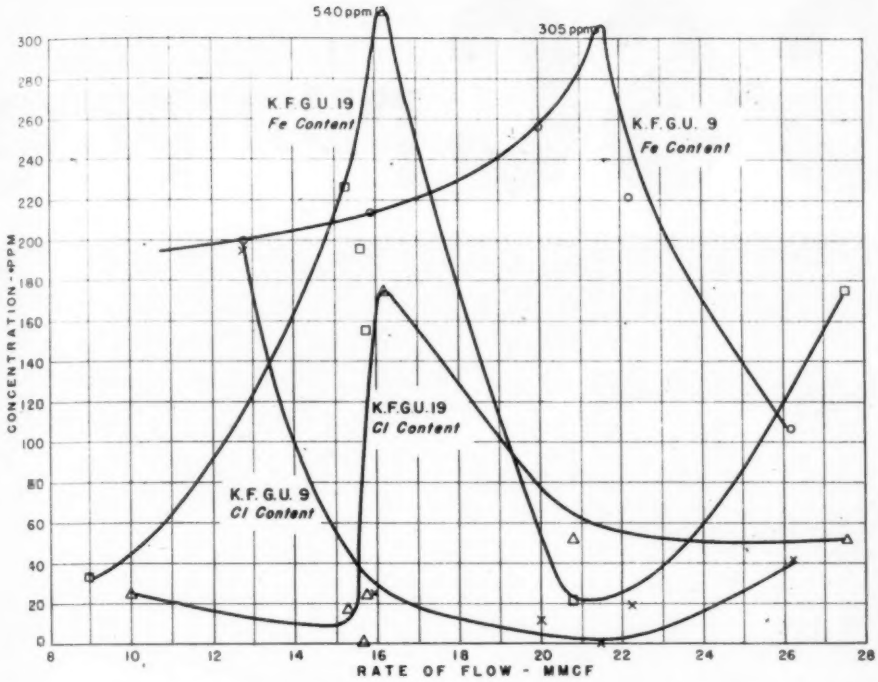


Fig. 2. Variation of iron and chloride content of condensed water with rate of flow.

lion cubic feet, whereas at 1850 lb. per sq. in. and a temperature of 85 to 90°F., a decrease in saturation to 3 gal. per million cubic feet is reached. Obviously, if it is assumed that saturation of the gas with water does occur at reservoir conditions, 20 gal. of free water (in liquid form) is present under wellhead conditions whereas slightly less than 40 gal. are condensed under conditions prevailing at the high pressure separator at the plant and in the experimental portable field separator. Actual determinations of the total amount of water produced in the high pressure separator at the plant yield values of 28 to 30 gal. per million cubic feet. This water constitutes the major factor in the corrosion encountered.

The total quantity of hydrocarbon liquid condensed was determined to be 40 gal. per gal. of condensed water. Of this amount of condensate, a rough estimate of the relative amount present as liquid at wellhead conditions of temperature and pressure yields a value of 20 gal. per gal. of water. Thus, on an average, water constitutes approximately 5 per cent of the material present in the flowing gas stream at wellhead pressure and temperature. The volumes of water condensed in individual trials with the portable field separator at the various wells vary greatly from a minimum of 5 gal. per million cubic feet per day to a maximum of 500 gal. per million cubic feet per day.

In Fig. 2 is plotted the data from two wells, K.F.G.U. 9 and K.F.G.U. 19, showing the total iron concentration and the chloride content in parts per million in the produced water versus the rate of flow of gas in million cubic feet per day. The iron content of the water from K.F.G.U. 9 increases with rate of flow of gas up to about 21 million cu. ft. per day and then decreases rapidly with increasing rates of flow. A much lower value of iron is determined at the rate of 26.2 million cu. ft. per day than any of the concentrations found at lesser rates of flow. The net result of lower iron concentrations is most likely due to a combination of various diffusion rates and chemical reaction rates and is in agreement with the findings of Yushkevich, Zhavorankov, and Zel'venskii[19] that the absorption coefficient of carbon dioxide in water was directly proportional to the intensity of wetting of the surface yet the rate of increase of this absorption coefficient decreased with lessened wetting. The chloride concentration varies indirectly with the iron content of the water, reaching a minimum at the point of maximum iron content and rising slightly as the iron concentration decreases. Somewhat different conditions apparently exist in K.F.G.U. 19 though this is a multiple completion well and not as much reliance can be placed in the data as the relative rates of flow of gas from the casing and tubing were not observed. The range of variation in flow rate is comparable to that in K.F.G.U. 9; however, discounting the rather nondeterminate factors, it may be seen that a rather sharp reduction in the iron content of the water occurs with increased rate of flow beyond 16 million cu. ft. per day and increases again as a rate of 27.5 million cu. ft. per day is reached.

In order to determine whether or not any definite relationship existed between the dissolved carbon dioxide, pH, and bicarbonate ion these values were plotted against the rate of flow. The results are presented in the curves of Fig. 3(a) and 3(b). As the rate of flow of gas increases, the pH increases slightly until a maximum is reached corresponding to the same rate of flow at which a maximum in the iron concentration of the water occurs as shown in Fig. 2. A rapid decrease in pH then occurs accompanied by a sharp rise in the dissolved carbon dioxide content, which also subsequently decreases somewhat with increasing flow.

(Continued on Page 64)

TABLE 2

Rate factors influencing corrosion of steel by dissolved CO_2

I. Rate of flow. — Related to:
1. Wellhead temperature and pressure
2. Water produced from well bore
3. Water condensed, thickness of film
4. Chemical composition of water condensed
5. Hydrocarbon condensate

II. Rate of absorption of CO_2. — Related to:
1. pH, diss. CO_2, HCO_3, of condensed water
2. Size of drop considered or thickness of water film
3. Iron content of condensed water
4. Hydrocarbon liquid film
5. Temperature
6. Pressure
7. Rate of flow
8. Composition of gas

$$CO_2\ (gas) \rightleftarrows CO_2\ (dissolved) \xrightarrow{H_2O} H_2CO_3 \rightleftarrows H^+ + HCO_3^- \rightleftarrows H^+ + CO_3^=$$

III. Rates of reaction involving the metal. — Related to:
1. Absorption of CO_2
2. Amount of water wetted surface, i.e., ratio of liquid hydrocarbon:water
3. Removal of reaction products, i.e., products of corrosion
4. Secondary reactions
5. Pressure and temperature

$$2H_2CO_3 + Fe \rightleftarrows Fe(HCO_3)_2 + H_2^\circ$$
(metal)

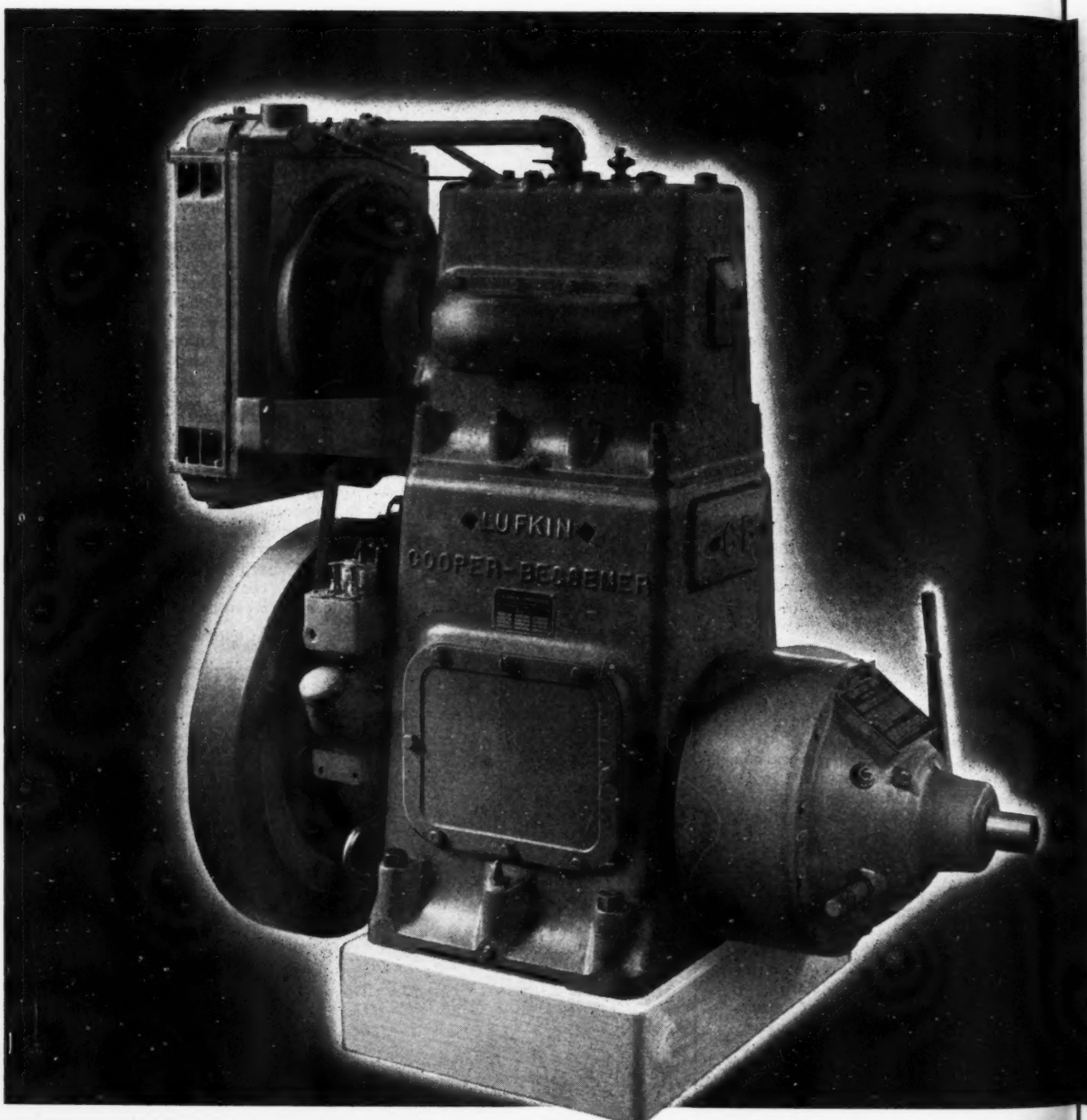
Actually

$$2H^+ + Fe^\circ \rightleftarrows Fe^{++} + H_2^\circ$$
(metal)

Possibility of secondary reaction

$$Fe(HCO_3)_2 + 2HOH \rightleftarrows Fe(OH)_2 + 2H_2CO_3 \rightleftarrows 2H^+ + 2HCO_3^- \rightleftarrows 2H^+ + CO_3^=$$

G-SC pumping e



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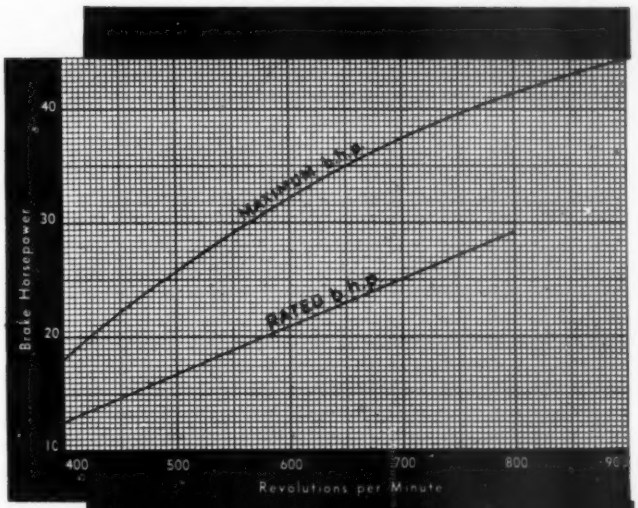

B. H. P.	25 - 35
R. P. M.	600 - 800
Bore	5½"
Stroke	7"
No. of Cylinders	2
No. of Flywheels	1
Rotation (when facing flywheel)	Clockwise*
Piston Speed (feet per minute)	700 - 933
Diameter Exhaust Pipe	4"
Diameter Air Intake Pipe	4"
Diameter Fuel Gas Pipe	2"
Diameter Water Inlet Pipe	1¼"
Diameter Water Outlet Pipe	1¼"
Diameter Starting Air Pipe	½"
Overall Height from Bottom of Base	4' 1¾"
Overall Length with Clutch	5'
Overall Width	2' 6"
Min. Cu. Yds. Concrete in Foundation	1

*Rotation designated as "clockwise" indicates direction of rotation when standing at flywheel and facing engine.

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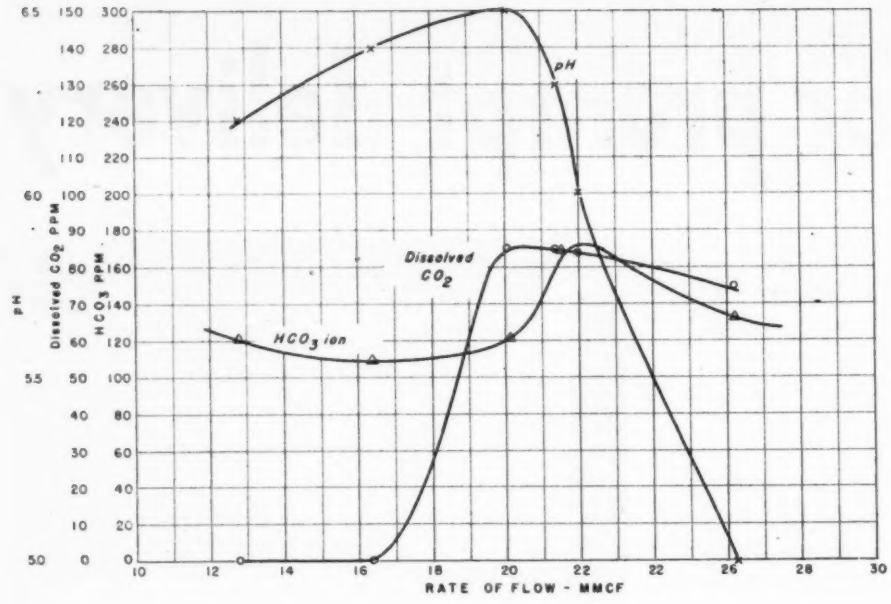

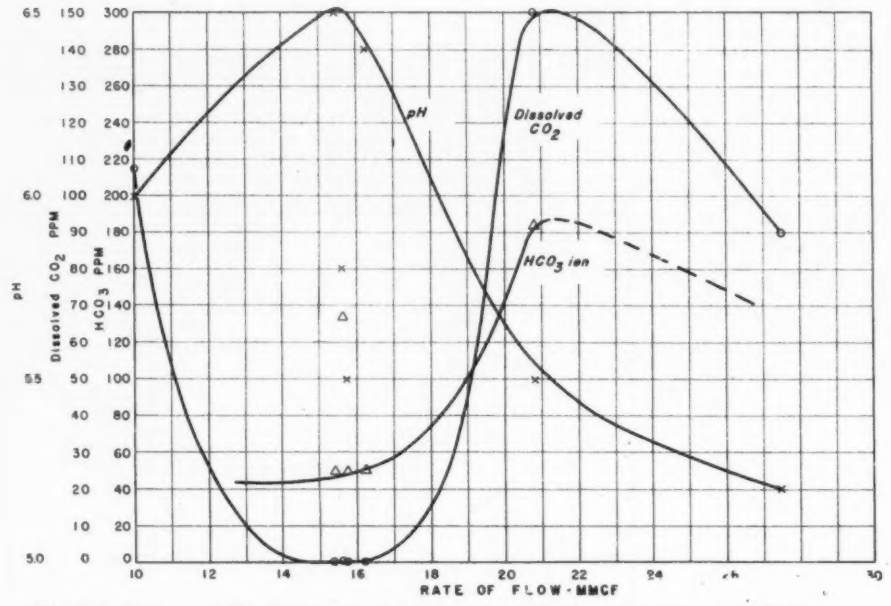

Fig. 3a (top) and 3b (bottom). Variation in pH, dissolved CO_2 and HCO_3 in concentration in condensed water, from Katy field gas unit 9. From January 31 to March 26, 1944, for Fig. 3a, and from January 25 to March 24, 1944, for Fig. 3b.

(Continued from Page 61)

There is less noticeable change in the bicarbonate ion concentration.

To account for the correlation between the decrease in iron concentration with decreased pH, occasioned by greater amounts of dissolved carbon dioxide, requires that the rate of reaction of hydrogen ion with metallic iron is less than the rate of absorption of carbon dioxide by water or that the increased rate of flow of gas removes the water film on the metal before reaction between the hydrogen ion (of the carbonic acid) and the iron has proceeded very far. More or less, the same general agreement, involving the three rates previously outlined (refer to Table 2) is obtained at lower rates of flow of gas. In the case of the increased solution of iron with increasing pH and lesser amounts of dissolved carbon dioxide, the rate apparently is such that sufficient time elapses in the interval between the initial absorption of carbon dioxide by the water film or droplet to allow the reaction between the hydrogen ion and iron to proceed nearly to completion while the drop or film is in contact with the metal. The co-presence of a non-aqueous film would also undoubtedly influence the rate of absorption of carbon dioxide though Klyucharev[8] found that 0.1 millimeter thick film of crude petroleum or machine oil on water had practically no effect on the rate of solution of carbon dioxide in water.

The preceding discussion leads to a plausible explanation of the mechanism of reaction for the corrosion encountered and one which lends itself to laboratory investigation. It is therefore tentatively proposed that any laboratory study that might be initiated include a consideration at the appropriate temperature and pressure of the variables discussed, namely, (1) the rate of absorption of carbon dioxide from the gas to the liquid film at various rates of flow, (2) the velocity of reaction of water saturated with carbon dioxide and steel, (3) the effect of varying the ratio of condensed water to hydrocarbon condensate, and (4) the effect of varied rates of flow on fluid film thickness, rate of movement of fluid films, or droplet behavior at high rates of flow.

Summary. An examination of data, considered to be representative, available from a well in the Katy field, Waller County, Texas, indicates that the corrosion of steel may be correlated with the rate of flow of gas, which in turn is believed to contribute largely to the rate of absorption of carbon dioxide. Evidence is presented to show that the rate of reaction of dissolved carbon dioxide with steel at the pressures and temperatures encountered in the operation of gas and condensate wells seems dependent on the rate of absorption of carbon dioxide and the length of time the fluid film is in contact with the metal. The continuity of a fluid film is questionable at higher rates of flow. It is believed that the ratio of condensed water to hydrocarbon condensate is also of considerable importance in the corrosion of steel by high pressure gas.

It is felt that invaluable information may be gained by a laboratory study of the problem of corrosion occurring in high pressure gas and condensate wells. An essential part of any program of laboratory research of the problem should be a consideration of the factors of rate of flow of gas, absorption of carbon dioxide by fluid films, rate of reaction of dissolved carbon dioxide on steel at prevailing temperatures and pressures, fluid film behavior at high flow rates, and the effect of water-hydrocarbon condensate ratio.

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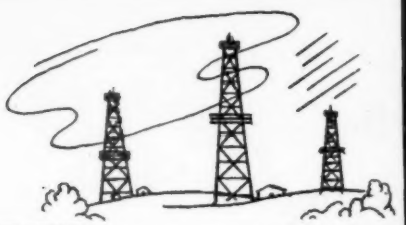

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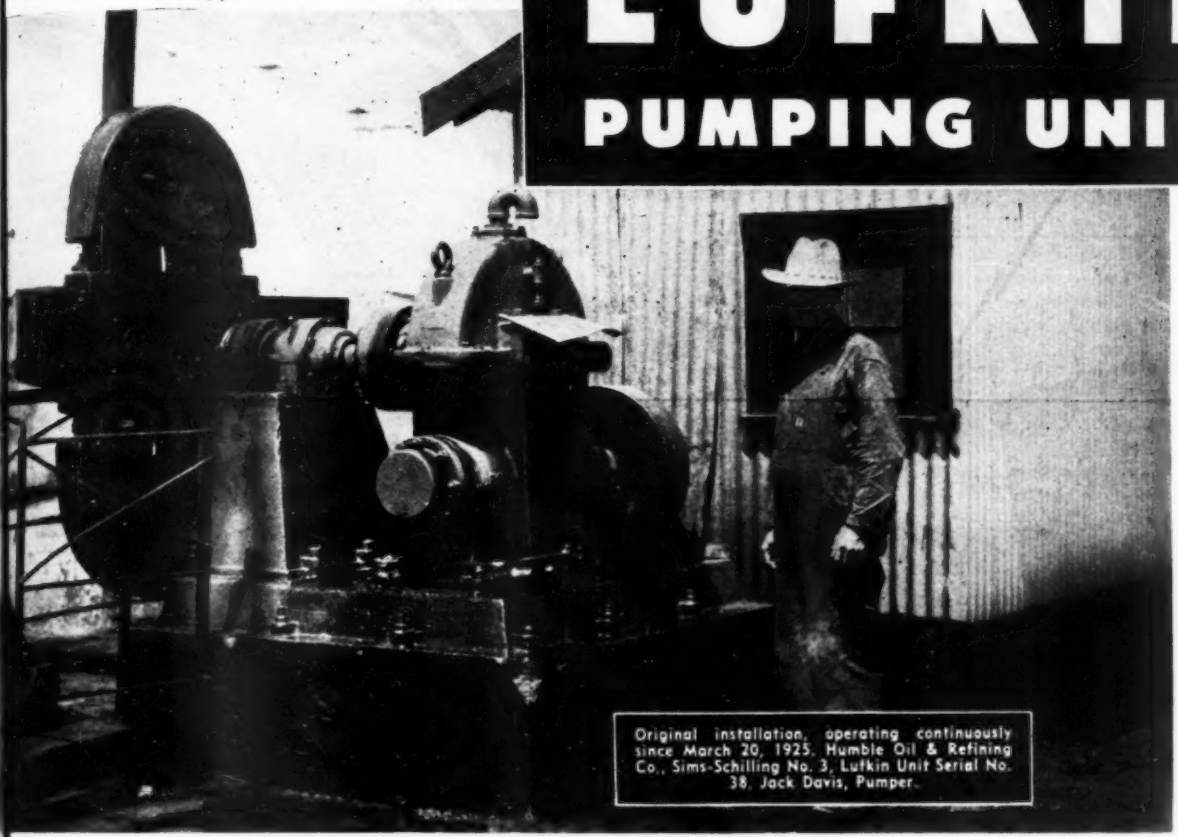

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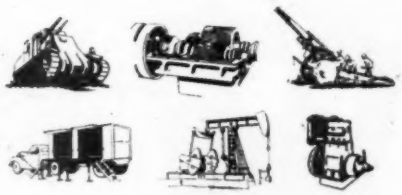

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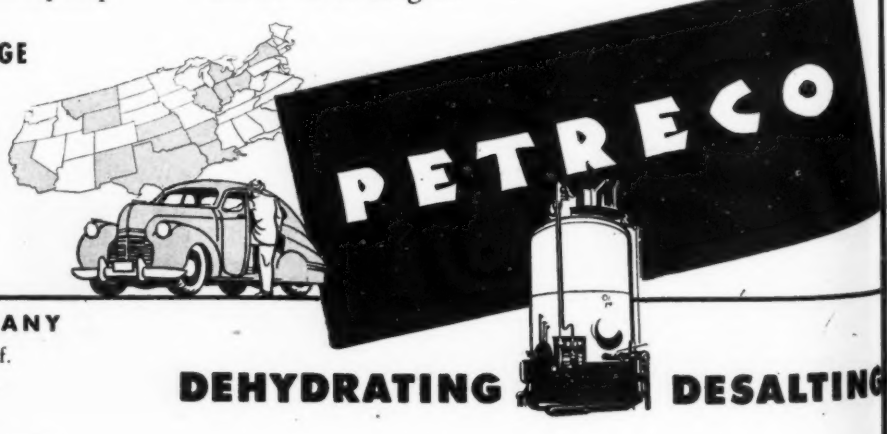

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DEHYDRATING DESALTING

Method of Approach to Determine The Optimum Spacing of Wells

By N. VAN WINGEN*

Tested plan shows how to calculate spacing in unit-operated field for largest ultimate profit

EXCLUSIVE The problem of the proper spacing of oil and gas wells has been the subject of many discussions. In past years, the interest in the problem has perhaps often been predominantly academic in nature because multiplicity of ownership, and consequently intensively competitive conditions, set a pattern where offset development rather than engineering principle determined the number of wells to be drilled ultimately on any given property. In recent times, however, there has been an increasing number of instances where entire pools either have been owned singly or diversified interests have been consolidated for the purpose of forming a single unit of operation. It is apparent that in the absence of competitive offset development, the consideration of optimum spacing of wells is of paramount interest for the purpose of realizing the highest ultimate economic returns.

In order to arrive at a method to determine the optimum spacing of wells to yield the maximum net profit under unit operation, a group of engineers and geologists in California has made an extensive study of well spacing problems in a symposium sponsored by the Pacific section of the American Association of Petroleum Geologists. This group consisted of the following: F. S. Parker, Petroleum Administration for War, chairman; Stanley Herold, War Production Board, group leader; E. R. Atwill, Union Oil Company; E. J. Bartosh, Bankline Oil Company; G. H. Bowes, Continental Oil Company; W. R. Cabeen, consultant; D. M. Cook, Walker S. Clute, consultant; R. R. Crandall, consultant; C. A. Davis, Richfield Oil Corporation; E. L. Davis, Petroleum Administration for War; C. J. Dean, General Petroleum Corporation; H. L. Driver, Standard Oil Company (California); W. S. Eggleston, Union Oil Company; E. A. Gray, Richfield Oil Corporation; G. B. Gariepy, Ohio Oil Company; J. M. Hillard, captain, U. S. Army Air Force; V. L. King, consultant; E. D. Lynton, Bureau of Economic Warfare; C. L. Moore, Petroleum Administration for War; W. S. Payne, ensign, U. S. Naval Reserve; R. O. Pollard, Jr., Richfield Oil Corporation; J. L. Porter, Richfield Oil Corporation; R. G. Reese, Standard Oil Company (California); L. H. Shearer, Core Laboratories, Inc.; D. H. Sheldon, R. E. Havenstrite, Operator; H. H. Sullwold, U. S. Geological Survey; E. G. Trostel, Petroleum Administration for War; E. H. Vallat, Ohio Oil Company; N. Van Wingen, Richfield Oil Corporation; E. W. Webb, Continental Oil Company, and A. F. Woodward, U. S. Army.

*Senior Production Engineer, Richfield Oil Corporation.

The study was led by Stanley Herold who presented the material in a series of seven lectures introducing the graphical method that is fundamental in this article. W. S. Eggleston provided the physical and geological data on the zone taken as example. The present article has been adapted for publication from lecture notes and curves prepared by N. Van Wingen and C. A. Davis of the Richfield Oil Corporation. All points in Herold's lectures that represent expressions of opinion or judgment were fully discussed by the group and the final form incorporates the additions and modifications brought out by the discussions.

The Bell Zone of the Santa Fe Springs Field, California, was used as an example to demonstrate the method. The ultimate production of 724 bbl. per acre-foot from an average thickness of 115 ft. of sand, the number of wells, spacing, and other physical data are well established. The calculation, however, was made as of the initial period of development. The results of the calculation show an expectable net profit of $59,500,000 at 1.7 acres spacing as compared with $36,000,000 expectable at the actual spacing of 14 acres per well.

The method is general and can be applied to any field with results that will compare in accuracy to the available data. This article does not profess to present a final formula of solution, but it does attempt to develop a method of approach that is sufficiently general in character to be applicable to any specific set of field conditions. The reliability of any such analysis will be a direct function of the extent of available basic data and the skill and resourcefulness of the engineer in the interpretation and application of such data to the method here outlined.

▼ **Definition of the problem.** Optimum well spacing may be defined as that spacing density of wells, without abnormal competitive conditions, that will result in the greatest ultimate profit to the operator. Defined in these terms, it is implied that economic considerations are intimately associated with the problem and it is thus apparent that a solution, consistent with the definition as stated, will not give the greatest ultimate return in barrels to be recovered, irrespective of cost, nor the minimum monetary amount to be expended in the event the time factor of recovery were to be neglected.

For the purpose of developing the generalized form of the analysis, the following assumptions were made upon which the method is to be based:

1. The reservoir has been considered to be a homogeneous sand body in which no lenticularity exists.
2. A unit area equal to one square mile has been taken in which the reservoir involved represents mid-flankal conditions, that is, a normal oil zone with a normal saturation of gas.
3. It has been taken that no faulting exists within the unit area of one square mile.
4. Fields with extensive gas caps or those subject to active water drives will require special treatment. By such treatment gas cap and edge well areas would be developed to some other optimum spacing and should involve the drilling of less wells per unit of area than would be required for the average mid-flankal well.

Any method of determining optimum well spacing involves the prediction of the following factors:

1. Determination of the tank oil in place. This implies that initially a wide spacing development program is to be adhered to in order to delineate accurately the productive limits of the reservoir and to establish the necessary basic characteristics of the producing horizon.
2. Cost of drilling in terms of dollars per foot, or dollars per well.
3. Initial and future production rates.
4. Operating costs, taxes, insurance, and overhead.
5. Future values of oil, gas, and gasoline.
6. Economic life of the well.
7. Determination of a present worth factor to be applied in discounting future earnings.

For the purpose of carrying through a sample analysis on a quantitative basis, application was made to an actual California reservoir, the Bell Zone of the Santa Fe Springs field, whose characteristics can be considered to be well established due to its now having reached a relatively advanced stage of depletion. Calculations were made to apply hypothetically to reservoir conditions as of the time of discovery. When applied to an actual new discovery, a similar completeness of basic data can be approximated provided the initial development is on a sufficiently wide spacing pattern so that the reservoir can be delineated by the drilling of a relatively small number of wells.

For the purpose of arriving at the re-

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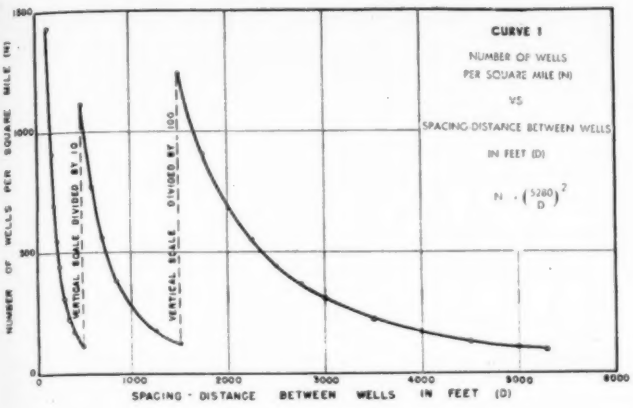
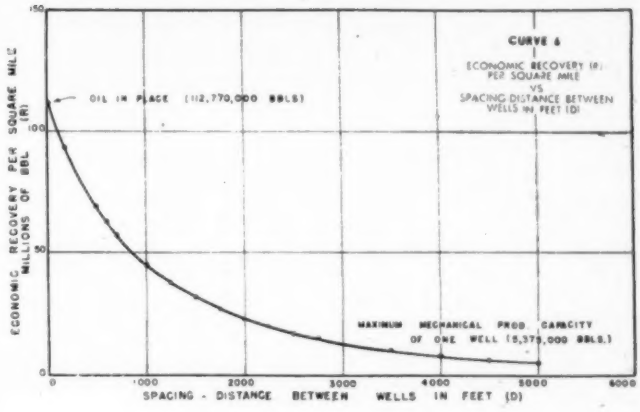
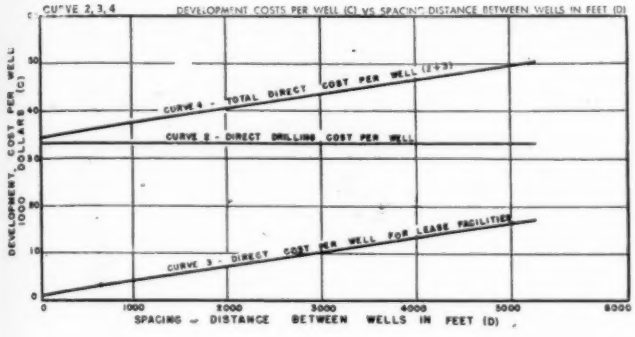
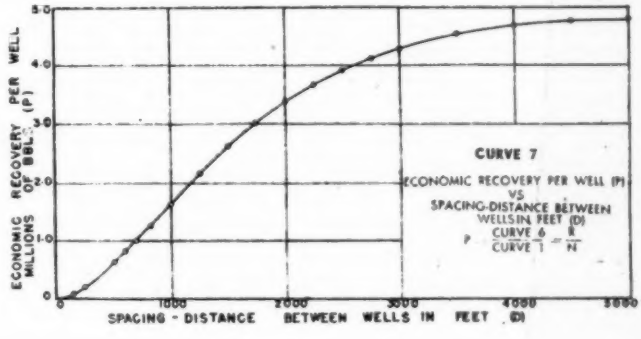
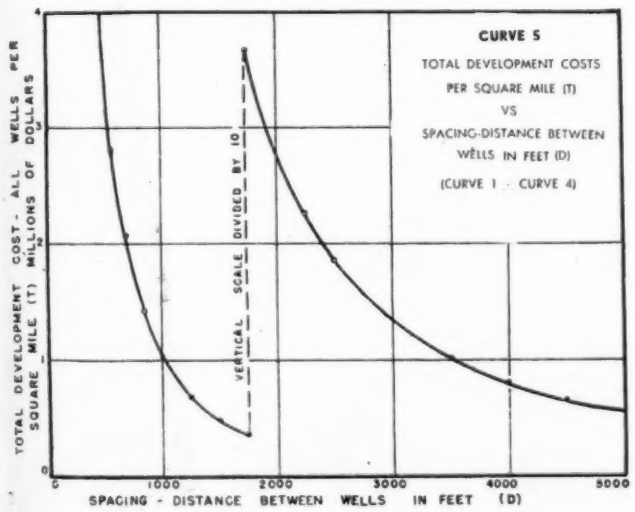
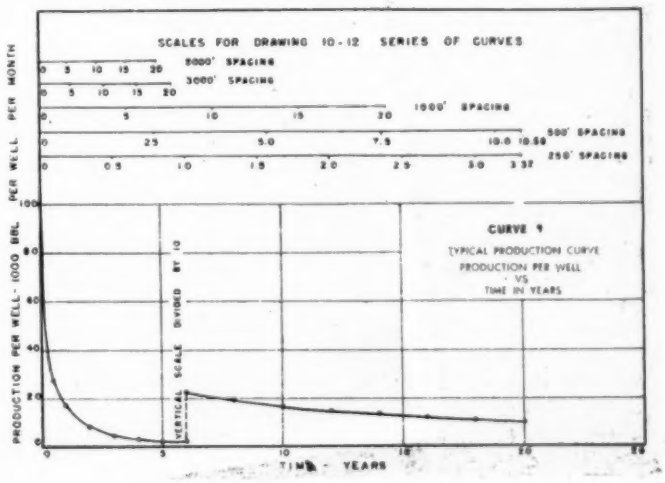

CURVE 1
NUMBER OF WELLS PER SQUARE MILE (N) VS SPACING-DISTANCE BETWEEN WELLS IN FEET (D)
$N = \left(\frac{5280}{D}\right)^2$
VERTICAL SCALE DIVIDED BY 10
VERTICAL SCALE DIVIDED BY 100
NUMBER OF WELLS PER SQUARE MILE (N)
SPACING - DISTANCE BETWEEN WELLS IN FEET (D)


CURVE 6
ECONOMIC RECOVERY (R) PER SQUARE MILE VS SPACING-DISTANCE BETWEEN WELLS IN FEET (D)
OIL IN PLACE (112,770,000 BBLS)
MAXIMUM MECHANICAL PROD. CAPACITY OF ONE WELL (5,379,000 BBLS.)
ECONOMIC RECOVERY PER SQUARE MILE (R) MILLIONS OF BBL
SPACING - DISTANCE BETWEEN WELLS IN FEET (D)


CURVE 2, 3, 4
DEVELOPMENT COSTS PER WELL (C) VS SPACING DISTANCE BETWEEN WELLS IN FEET (D)
CURVE 4 - TOTAL DIRECT COST PER WELL (2+3)
CURVE 2 - DIRECT DRILLING COST PER WELL
CURVE 3 - DIRECT COST PER WELL FOR LEASE FACILITIES
DEVELOPMENT COST PER WELL 1000 DOLLARS (C)
SPACING - DISTANCE BETWEEN WELLS IN FEET (D)


CURVE 7
ECONOMIC RECOVERY PER WELL (P) VS SPACING-DISTANCE BETWEEN WELLS IN FEET (D)
CURVE 6 / CURVE 1 = R / N
ECONOMIC RECOVERY PER WELL MILLIONS OF BBL (P)
SPACING - DISTANCE BETWEEN WELLS IN FEET (D)


CURVE 5
TOTAL DEVELOPMENT COSTS PER SQUARE MILE (T) VS SPACING-DISTANCE BETWEEN WELLS IN FEET (D)
(CURVE 1 · CURVE 4)
VERTICAL SCALE DIVIDED BY 10
TOTAL DEVELOPMENT COST - ALL WELLS PER SQUARE MILE (T) MILLIONS OF DOLLARS
SPACING - DISTANCE BETWEEN WELLS IN FEET (D)


SCALES FOR DRAWING 10-12 SERIES OF CURVES
3000' SPACING
1000' SPACING
500' SPACING
250' SPACING
CURVE 9
TYPICAL PRODUCTION CURVE
PRODUCTION PER WELL VS TIME IN YEARS
VERTICAL SCALE DIVIDED BY 10
PRODUCTION PER WELL - 1000 BBL PER WELL PER MONTH
TIME - YEARS

quired optimum spacing pattern, it was considered most expedient to proceed on a graphical basis throughout and to present all basic data in this manner whenever possible in order to visualize better the magnitude and significance of the various factors as they affect the final outcome. On such a basis then, a series of graphs was established to serve in the derivation leading to the final net-profit-versus-spacing curve.

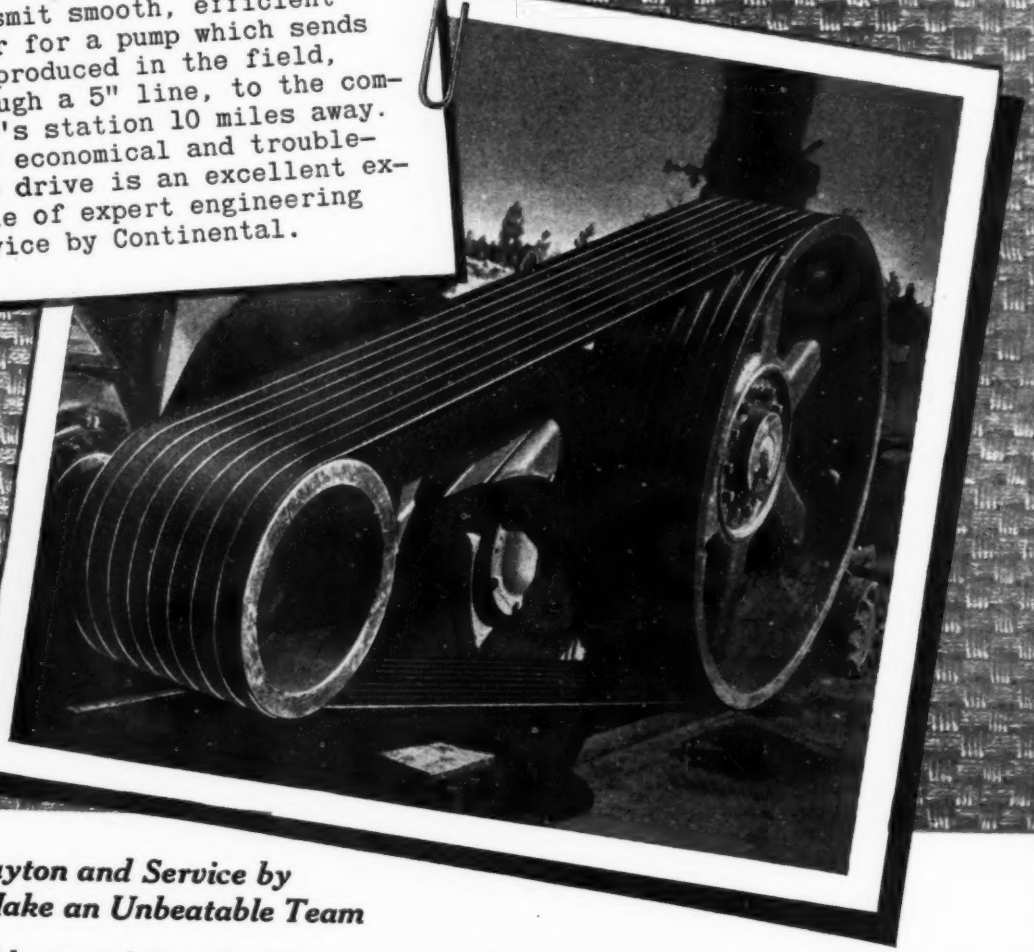
▼ **Structure and reservoir characteristics.** The structure of the reservoir is a gently folded, non-faulted anticlinal dome approximately elliptical in shape with major and minor axis, respectively, 7900 and 5200 ft. in length. The structure had an original closure to the oil water contact at 3700 ft. subsea, of approximately 250 ft., and an areal extent within this contour of 730 acres. The productive horizon is divided into two intervals: An upper zone, with 135 ft. penetration of which 103 ft. is productive oil sand, and a lower zone, with a penetration of 145 ft. of which 115 ft. is productive sand. Under the original reservoir conditions, only wells drilled within the confines of the 3475 ft., subsea contour, comprising an area of 76 acres could penetrate fully, however, the productive thickness of both of these intervals. The total reservoir volume of the two intervals combined is 84,800 acre-ft. The average porosity has been determined to be 29 per cent and the interstitial water 21 per cent of the total pore volume. Hence, the total pore volume available for hydrocarbon is 151,000,000 bbl. or 129,000,000 tank bbl. of oil in place (formation volume factor 1.17). This is equivalent to 1519 bbl. per acre-ft. There is no indication of an original gas cap having been present in either of the two producing intervals.

To January 1, 1941, the reservoir had produced a total of approximately 51,000,000 bbl., and it is estimated that an additional 11,000,000 bbl. remain to be recovered, thus giving a total indicated ultimate recovery of 61,000,000 bbl. or 724 bbl. per acre-ft., which represents a recovery factor of 47.6 per cent. A total of 184 wells have been drilled into the zone, but the number of producing wells have at no time exceeded 86, the rest having been either deepened to lower producing intervals or plugged back to upper zones. The average number of producing wells throughout the life of the field to January 1, 1941, has been 52, which corresponds to a spacing density of one well to 14 acres, or a spacing distance of 782.5 ft. between wells.

▼ **Development of the curve series.**

SPECIALIZED AND EXPERT IS THIS V-BELT SERVICE FOR THE PETROLEUM INDUSTRY

These 8 Dayton V-Belts are teamed up with an engine to transmit smooth, efficient power for a pump which sends oil produced in the field, through a 5" line, to the company's station 10 miles away. This economical and trouble-free drive is an excellent example of expert engineering service by Continental.



V-Belts by Dayton and Service by Continental Make an Unbeatable Team

If you're bothered by wasteful, costly drives, let a Continental representative help you quickly convert them into efficient V-Belt Drives. They have what it takes to hold and run smoothly and economically under the rigorous work and weather conditions of the Petroleum Industry.

Remember, Dayton Rubber stands for Technical Excellence in natural and synthetic rubber! Continental stands for expert and specialized service to the Petroleum Industry! That combination—backed by stocks of Dayton V-Belts strategically located to serve you—just can't be beat!

THE CONTINENTAL SUPPLY COMPANY
General Offices: **DALLAS, TEXAS**

Maintain Victory Speeds • Conserve Your Tires

V-Belts by Dayton Rubber
The Mark of Technical Excellence in Synthetic Rubber

SERVICE BY Continental

Curve 1 simply represents the number of wells per square mile for various spacing distances between wells.

Curve 2 represents the average drilling cost per well. This cost is based upon a unit drilling charge of $8.60 per ft. for the average depth of 3850 ft., or a total of $33,100 per well for all spacing densities. Items chargeable to the drilling cost of a well were considered to be:

1. Well and all appurtenances
2. Gas traps
3. Oil and gas lines to main header
4. Production tanks for the well if located at the well site.

Curve 3 represents the direct cost of the prorata share of lease facilities for the well. For the pool under consideration, this cost was taken to be 10 per cent of the drilling cost per well for a spacing of 660 ft. between wells or $3,310, and 50 per cent for a spacing of 5000 ft. or $16,550 (straight line relationship).

Curve 4 represents the total development cost per well and is thus obtained by adding curves 2 and 3.

Curve 5 represents the total development cost of all wells per square mile. It is apparent that these data are obtained by multiplying cost values (C) from curve 4 by the corresponding number of wells per square mile (N) as obtained from curve 1.

Curve 6 represents the total economic recovery per square mile for various spacing patterns. It is apparent that this curve contains the key to the solution of the spacing problem. No adequate analytical method has yet been devised, however, to calculate accurately such a relationship for any given type of reservoir, and it is thus only possible to make an estimate guided by the best available information regarding the particular reservoir for which the analysis is being made. For the purpose of this problem, the following points are arbitrarily taken:

Zero spacing distance: 100 per cent recovery of the tank oil in place or 112.77 million bbl.

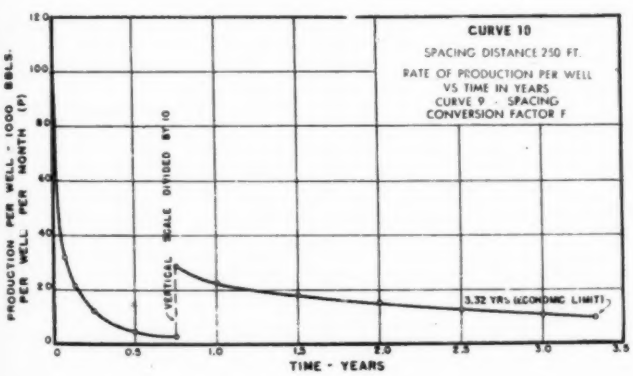
782.5-ft. spacing distance (actual average field spacing): 53.75 million bbl.

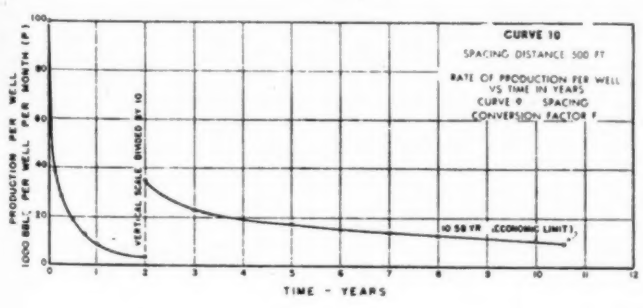
5000-ft. spacing distance: 5.375 million bbl. (arbitrary).

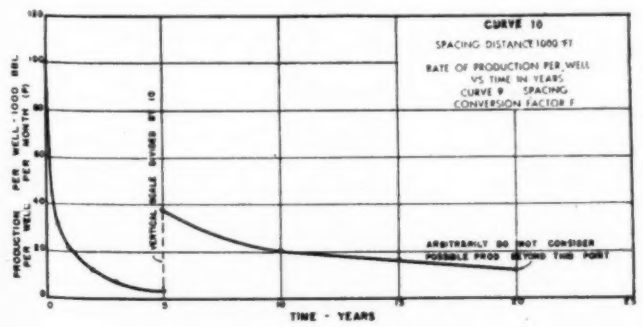
In establishing the final point representing the extreme case of a spacing distance between wells of 5000 ft., the limiting effect imposed by the mechanical condition of the borehole was considered as a prime factor reducing the recovery. It was felt that approximately 5,000,000 bbl. represent the probable maximum amount that could be expected to be recovered per well in this field.

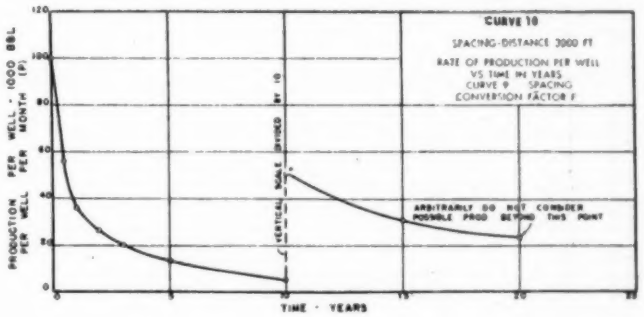
Curve 7 represents the economic recovery per well for various spacing patterns. This curve is thus obtained by dividing recoveries per square mile (R) as given by curve 6 by the corresponding number of wells (N) from curve 1. By means of curve 7, a check on the selection of the type curve 6 can be made. Curve 7, as derived from curve 6, should be a reasonable and continuous function with no anomalies. Failure of curve 7 to be continuous or the presence of points of inflection constitute direct evidence that the assumptions made in the derivation of curve 6 were incorrect.

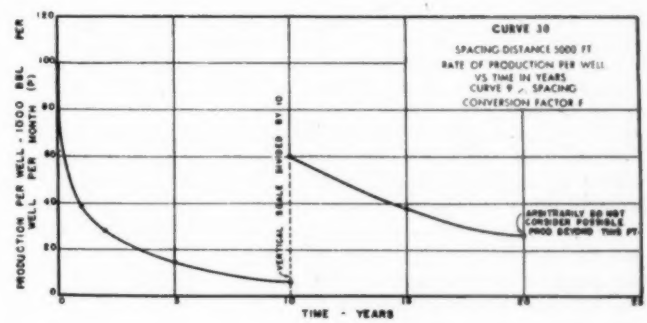
Curve 8 represents the initial production per well per month for various spacing patterns. This curve was taken as a straight horizontal line with a value of 100,000 bbl. per month, which figure corresponds to the actual initial production rates as observed for the first completions in the zone under consideration. In order that this curve may aptly apply to closer spacing, it is implied that the rate

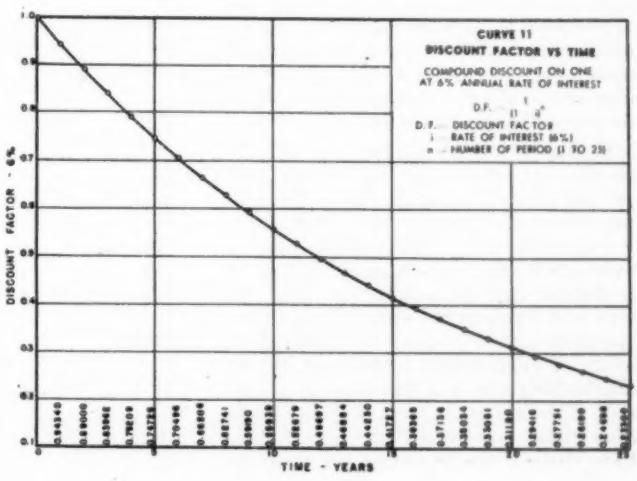

CURVE 10
SPACING DISTANCE 250 FT.
RATE OF PRODUCTION PER WELL VS TIME IN YEARS
CURVE 9 SPACING CONVERSION FACTOR F
PRODUCTION PER WELL - 1000 BBLS. PER WELL PER MONTH (P)
VERTICAL SCALE DIVIDED BY 10
3.32 YRS (ECONOMIC LIMIT)
TIME - YEARS

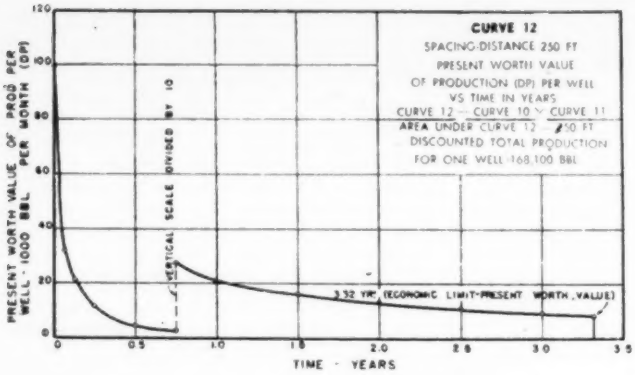

CURVE 10
SPACING DISTANCE 500 FT
RATE OF PRODUCTION PER WELL VS TIME IN YEARS
CURVE 9 SPACING CONVERSION FACTOR F
PRODUCTION PER WELL 1000 BBL PER WELL PER MONTH (P)
VERTICAL SCALE DIVIDED BY 10
10.58 YR (ECONOMIC LIMIT)
TIME - YEARS

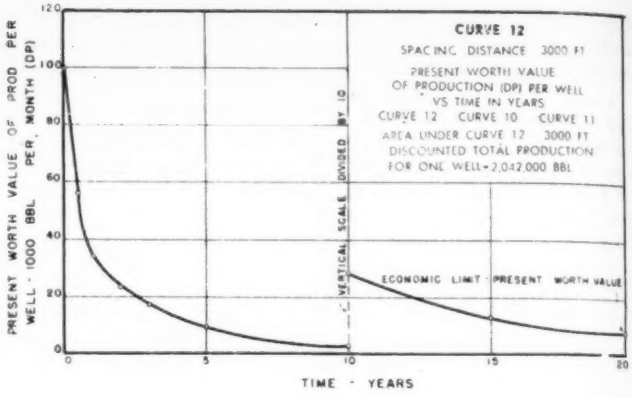

CURVE 10
SPACING DISTANCE 1000 FT
RATE OF PRODUCTION PER WELL VS TIME IN YEARS
CURVE 9 SPACING CONVERSION FACTOR F
PRODUCTION PER WELL - 1000 BBL PER MONTH (P)
VERTICAL SCALE DIVIDED BY 10
ARBITRARILY DO NOT CONSIDER POSSIBLE PROD BEYOND THIS POINT
TIME - YEARS

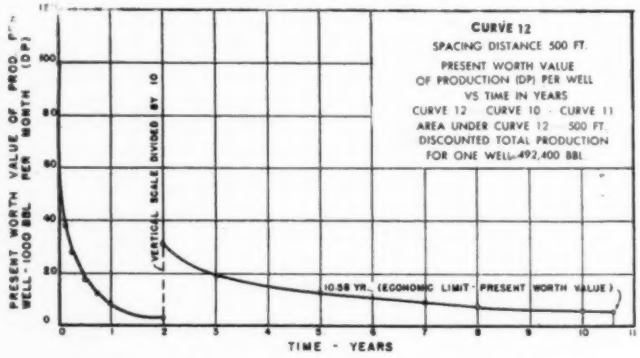

CURVE 10
SPACING DISTANCE 2000 FT
RATE OF PRODUCTION PER WELL VS TIME IN YEARS
CURVE 9 SPACING CONVERSION FACTOR F
PRODUCTION PER WELL - 1000 BBL PER MONTH (P)
VERTICAL SCALE DIVIDED BY 10
ARBITRARILY DO NOT CONSIDER POSSIBLE PROD BEYOND THIS POINT
TIME - YEARS

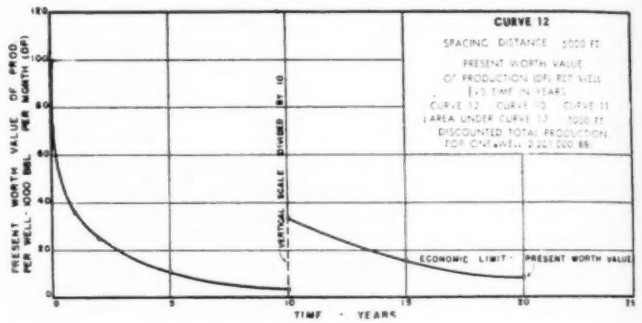

CURVE 10
SPACING DISTANCE 5000 FT
RATE OF PRODUCTION PER WELL VS TIME IN YEARS
CURVE 9 SPACING CONVERSION FACTOR F
PRODUCTION PER WELL - 1000 BBL PER MONTH (P)
VERTICAL SCALE DIVIDED BY 10
ARBITRARILY DO NOT CONSIDER POSSIBLE PROD BEYOND THIS PT.
TIME - YEARS

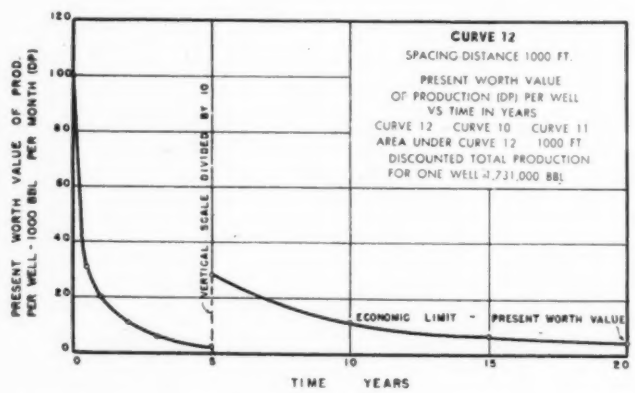

CURVE 11
DISCOUNT FACTOR VS TIME
COMPOUND DISCOUNT ON ONE AT 6% ANNUAL RATE OF INTEREST
D.F. = 1 / (1 + i)^n
D.F. = DISCOUNT FACTOR
i = RATE OF INTEREST (6%)
n = NUMBER OF PERIOD (1 TO 20)
DISCOUNT FACTOR - 6%
TIME - YEARS

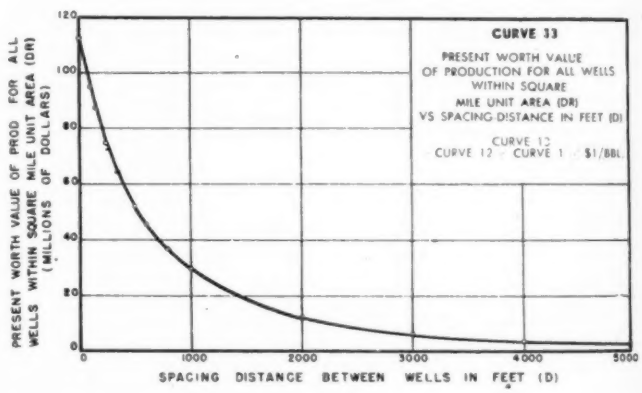

CURVE 12
SPACING DISTANCE 250 FT.
PRESENT WORTH VALUE
OF PRODUCTION (DP) PER WELL
VS TIME IN YEARS
CURVE 12 = CURVE 10 ÷ CURVE 11
AREA UNDER CURVE 12 = 250 FT.
DISCOUNTED TOTAL PRODUCTION
FOR ONE WELL=168,100 BBL
PRESENT WORTH VALUE OF PROD PER WELL - 1000 BBL PER MONTH (DP)
VERTICAL SCALE DIVIDED BY 10
3.32 YR. (ECONOMIC LIMIT-PRESENT WORTH VALUE)
TIME - YEARS


CURVE 12
SPACING DISTANCE 3000 FT.
PRESENT WORTH VALUE
OF PRODUCTION (DP) PER WELL
VS TIME IN YEARS
CURVE 12 = CURVE 10 ÷ CURVE 11
AREA UNDER CURVE 12 = 3000 FT.
DISCOUNTED TOTAL PRODUCTION
FOR ONE WELL=2,042,000 BBL
PRESENT WORTH VALUE OF PROD PER WELL - 1000 BBL PER MONTH (DP)
VERTICAL SCALE DIVIDED BY 10
ECONOMIC LIMIT - PRESENT WORTH VALUE
TIME - YEARS


CURVE 12
SPACING DISTANCE 500 FT.
PRESENT WORTH VALUE
OF PRODUCTION (DP) PER WELL
VS TIME IN YEARS
CURVE 12 = CURVE 10 ÷ CURVE 11
AREA UNDER CURVE 12 = 500 FT.
DISCOUNTED TOTAL PRODUCTION
FOR ONE WELL=492,400 BBL
PRESENT WORTH VALUE OF PROD PER WELL - 1000 BBL PER MONTH (DP)
VERTICAL SCALE DIVIDED BY 10
10.58 YR. (ECONOMIC LIMIT - PRESENT WORTH VALUE)
TIME - YEARS


CURVE 12
SPACING DISTANCE 5000 FT.
PRESENT WORTH VALUE
OF PRODUCTION (DP) PER WELL
VS TIME IN YEARS
CURVE 12 = CURVE 10 ÷ CURVE 11
AREA UNDER CURVE 12 = 5000 FT.
DISCOUNTED TOTAL PRODUCTION
FOR ONE WELL=2,221,000 BBL
PRESENT WORTH VALUE OF PROD PER WELL - 1000 BBL PER MONTH (DP)
VERTICAL SCALE DIVIDED BY 10
ECONOMIC LIMIT - PRESENT WORTH VALUE
TIME - YEARS


CURVE 12
SPACING DISTANCE 1000 FT.
PRESENT WORTH VALUE
OF PRODUCTION (DP) PER WELL
VS TIME IN YEARS
CURVE 12 = CURVE 10 ÷ CURVE 11
AREA UNDER CURVE 12 = 1000 FT.
DISCOUNTED TOTAL PRODUCTION
FOR ONE WELL=1,731,000 BBL
PRESENT WORTH VALUE OF PROD PER WELL - 1000 BBL PER MONTH (DP)
VERTICAL SCALE DIVIDED BY 10
ECONOMIC LIMIT - PRESENT WORTH VALUE
TIME - YEARS


CURVE 33
PRESENT WORTH VALUE
OF PRODUCTION FOR ALL WELLS
WITHIN SQUARE
MILE UNIT AREA (DR)
VS SPACING DISTANCE IN FEET (D)
CURVE 12
CURVE 12 = CURVE 1 ÷ $1/BBL
PRESENT WORTH VALUE OF PROD FOR ALL WELLS WITHIN SQUARE MILE UNIT AREA (DR) (MILLIONS OF DOLLARS)
SPACING DISTANCE BETWEEN WELLS IN FEET (D)

of development will be sufficiently rapid that all the wells will be completed within a reasonable time period. (This straight line curve is not shown.)

Curve 9 represents the rate of production for an average well versus time. For the purpose of this analysis this curve was based on actual production rate data observed to date for wells producing from the zone under consideration. For application to any new discovery, a curve of this nature would have to be estimated by analogy to similar fields, taking due cognizance of any restrictions that might be imposed by curtailment.

Curve 10 represents the rate of production for an average well versus time for any given spacing density other than that of curve 9, because this latter curve is applicable only to the spacing pattern to which the field was actually drilled. It is evident that the production time history will differ as the spacing density is changed. In the absence of curtailment or for a curtailment scheme where the allotment given is a function of potential, it is apparent that if more wells than those considered in curve 9 had been drilled, the recovery per well for any given time interval would have been less and conversely that more oil would have been recovered per well for the same given time interval if the spacing had been wider.

To ascertain the production time history for a spacing other than the one on which the empirical No. 9 was based, it was taken that this latter curve could be stretched or contracted dependent upon whether the new spacing is to be more or less than that of No. 9 (see variable time scales on curve 9, which can be used in lieu of constructing separate No. 10 curves) in other words, if we let:

L_1 = life for N_1 wells, L_2 = life for N_2 wells, D = distance between wells, R = economic recovery per square mile, and F = spacing conversion factor.

Then:

$$\frac{L_2}{L_1} = \frac{N_1}{N_2} \times \frac{R_2}{R_1} = \frac{(D_2)^2}{(D_1)^2} \times \frac{R_2}{R_1}$$

Hence:

$$L_2 = L_1 \times \frac{N_1}{N_2} \times \frac{R_2}{R_1} = L_1 \times \frac{(D_2)^2}{(D_1)^2} \times \frac{R_2}{R_1}$$

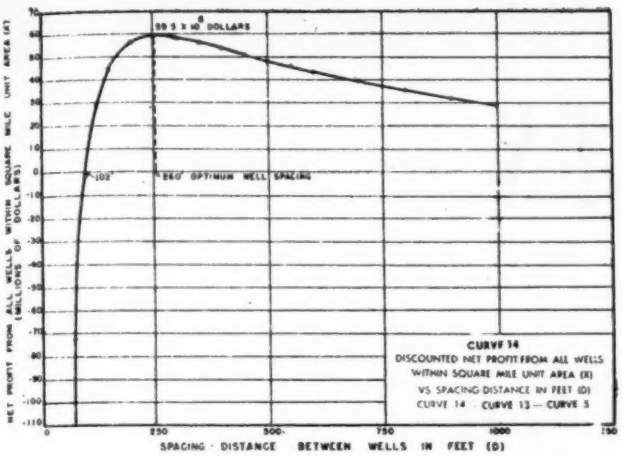
Hence:

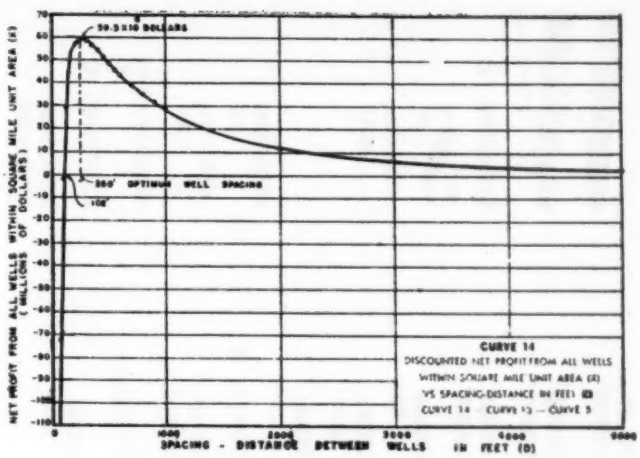
As curve 9 corresponds to $N_1 = 45.6$

$$L_2 = L_1 \times \frac{45.6}{N_2} \times \frac{R_2}{R_1} = F \times L_1$$

In this manner, then, a series of curves corresponding to each desired spacing pattern can be obtained by multiplying curve 9 by the corresponding value of F. In constructing these No. 10 curves, care should be taken that the area under each curve does not exceed the ultimate recoverable reserve figure as set up for the average well in curve 7 for the spacing pattern under consideration. For the extremely wide spacings, the productive life has arbitrarily been limited to 20 years. Production obtainable beyond this point was not included as its value, after discounting for present worth, was considered to be of negligible significance at the interest rate used in this problem.

Curve 11 shows the discount factor to be applied to obtain present worth values. Dependent upon the present value of money decided upon, this curve can be drawn on the basis of discount factors as given in a number of handbooks. For the purpose of this analysis,


CURVE 14
DISCOUNTED NET PROFIT FROM ALL WELLS
WITHIN SQUARE MILE UNIT AREA (E)
VS SPACING-DISTANCE IN FEET (D)
CURVE 14 - CURVE 13 — CURVE 5
SPACING - DISTANCE BETWEEN WELLS IN FEET (D)


CURVE 14
DISCOUNTED NET PROFIT FROM ALL WELLS
WITHIN SQUARE MILE UNIT AREA (E)
VS SPACING-DISTANCE IN FEET (D)
CURVE 14 - CURVE 13 — CURVE 5
SPACING - DISTANCE BETWEEN WELLS IN FEET (D)

an annual interest rate of 6 per cent was taken.

Curve 12. This curve series represents the present worth of rate of production versus time for various spacing densities. These curves are obtained by multiplying production rates from No. 10 curves for the various spacing patterns by the corresponding discount factors as given by curve 11. Hence as many No. 12 as No. 10 curves are obtained.

Curve 13 represents the present worth of the value of production from all the wells within the unit one square mile area for the various spacing patterns. It is obtained by multiplying respective areas under No. 12 curves by the corresponding number of wells (N) from curve 1 and by the net revenue in dollars per barrel of oil after royalty and costs. To ascertain this latter figure, the following factors were taken into consideration: Value of gross oil (31° A.P.I.), $1.20 per bbl. and average income factor for gas, gasoline, i.e., 20 per cent of the gross value of oil, or a total revenue for all hydrocarbons of $1.44 per bbl. Royalty was taken at 1/6, giving a net value of hydrocarbons, after royalty and before costs, of $1.20 per bbl. Average lifting cost, including taxes, insurance, supervision and overhead were estimated at $.20 per bbl., giving a net average value of hydrocarbons, after royalty and all costs, of $1.00 per bbl. This figure has been assumed to maintain, on the average, throughout the life of the field and was based on the current posted price of the hydrocarbon products.

Curve 14 represents the present worth of the net profit from all the wells per square mile for the various spacing patterns. This curve is obtained by subtracting the total development cost per unit area (T) as shown by curve 5 from the present worth of the value of the production from all the wells within the unit one square mile area (DR) as given by curve 13. This curve gives the answer to the problem of the optimum spacing for conditions of operation as outlined in the basic premises. The point of highest economic return is indicated clearly to be 260 ft. distance between wells or 1.7 acres per well. At spacing distances greater than the optimum, the curve becomes asymptotic to the horizontal axis (axis represents zero profit or loss) for it has been taken that lifting cost and overhead charges will be reduced as the production decreases. Should a portion of the lifting cost or overhead be taken as a fixed value, however, the curve may eventually cross the horizontal axis becoming asymptotic to some level below the horizontal, thus showing a net loss instead of a small profit for extremely wide spacing patterns.

It is apparent that with the exception of the optimum point, similar net profit values can be obtained at a spacing either greater or less than the optimum one. For example, the same profit is indicated for a 130-ft. as for a 950-ft. spacing distance between wells. It is also indicated by the trend of curve 14 that any error of judgment in the region where spacing distances are small will result in a far greater variance of the net profit than is the case when spacing distances are greater. Hence, because of the many variants that enter into the problem, the evaluation of which are difficult, it is apparent that in the case of doubt, a decision toward wider spacing is in the direction of conservatism. Nevertheless, as a further consideration of the same profit to the right and left of the optimum spacing, it is clear that the heavy demands of war will indicate the closer spacing, whereas the lighter demands of peace will be satisfied with the wider spacing.

▼ **Additional refinements.** Additional factors representative of special conditions in certain fields can be introduced into the basic framework of curves as outlined above. Some of these and their treatment can be summarized as follows:

1. Curtailment: Operations under curtailment will obviously affect the nature of curve 9. This curve can be redrawn for any given set of conditions, the only stipulation being that the area under this curve must always equal that of the total recoverable reserve. Curves subsequent to No. 9 can then be derived in a manner exactly correlative to the one as outlined in this problem. Such a procedure would thus merely lead to the construction of a new No. 10, No. 12, No. 13, and No. 14 series of curves.

2. For fields of anisotropic sand conditions, separate analyses can be made for the different portions of the field, determining the optimum economic spacing for each. In this manner, then, a series of curves can be prepared having optimum economic spacing for the abscissa and the following factors as ordinates: Sand thickness, structural position, permeability, and degree of well penetration.

3. Analyses can be made for various stages of the field's development, thus leading to a curve showing optimum economic spacing versus chronological time. It is apparent if development is delayed, that the optimum spacing distance between wells increases as the field progresses toward depletion.

4. A high rate of production, associated with close spacing affects the market price for oil. It is apparent that the oil price will decline whenever at any time the supply should greatly exceed the demand. This, in turn, will affect directly the optimum economic spacing as computed. To offset such a condition, curtailment will assist in maintaining the price structure, but will, in turn, diminish the present worth value of the net profit, due to deferment of the income. Suitable corresponding factors can be introduced to compensate for these conditions and the economic spacing recomputed accordingly.

5. If allowance for normal and excess profits taxes is desired, a curve 15 can be established to show these taxes. To this, curve 11 can be applied to obtain a curve 16, the present worth of such taxes. The subtraction of No. 16 from No. 14 gives the required curve. Spacing is increased by these taxes. ★ ★ ★

Lease Colombian Lands

Phillips Petroleum Company has leased the Simiti lands of about 1,000,000 acres in the Magdalena river valley of Colombia, South America, from Benedum Trees interest and the Leonary Oil Development Company of Pittsburgh. The track is 250 miles from Barranquilla, Colombia, a principal Caribbean seaport, and is about midway between the Barco lease in eastern Colombia and the Los Infantas field in central Colombia. The company will begin geological and geophysical work preparatory to drilling as soon as necessary arrangements are made with the Colombian government, it is said.

Wise refiners appreciate the cost-wise advantages of Houdry-licensed processes.

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THE REFINERY OF THE FUTURE

Part 2, Concluded

By R. G. LOVELL*

EXCLUSIVE

Residuum. The residual product from the wet gas fractionation would be hexanes and heavier. Its A.P.I. gravity would likely be about 58° with an initial boiling point of perhaps 150° and an end boiling point of from 300° to 380°, depending upon the efficiency of the fractionation. This leaves the product too low in volatility to use, as is, in motor gasoline, but by judicious blending of overages of lighter stocks, a satisfactory motor gasoline can result. Obviously, by subjecting the stock to precise fractionation several products of enhanced value can be had. It is also available for rerunning to Stoddard's solvent or painters naphtha.

▼ **Crude distillation.** The first cut shown from the atmospheric crude distillation was formerly considered simply as a good, low-sulphur, high octane stock, very suitable for use as a premium motor fuel. Emphasis on aviation gasoline has shown that, by more careful control of the fractionation, a stock can be produced that, when blended about 6 to 1 with isopentane, will supply about 50 per cent of the blend for 100-octane aviation gasoline. A substantially greater amount of 90-octane base stock can be made.

▼ **Straight run naphtha.** Not so long ago the heavier straight run naphtha formed a substantial part of motor gasoline. When blended with cracked stock for octane improvement and with natural gasoline for volatility and for sulphur dilution, it made a material that satisfied the market. The emphasis in all present processing is on aviation gasoline, diesel fuel, and bunker fuel and therefore cuts are adjusted to those ends. Lowering the endpoint to which the fraction is cut increases the supply of charge stock for catalytic cracking but bites deeply into the lighter end of the heavy naphtha to increase the available amount of the light stock for aviation gasoline. This has not only reduced the total quantity of the fraction, but has so reduced its blending qualities that it becomes a liability rather than an asset to a high grade motor gasoline blend.

It has been shown in the drawing, therefore, as being charged to a catalytic reforming unit, where a worthwhile percentage of it is transformed into a product of better characteristics from all angles, with the residue being charged to another unit in the refinery, about which more will be said later.

▼ **Diesel fuel.** The words, diesel fuel, fail to describe properly the characteristics or potentialities of the next heavier cut shown. Boiling range of a stock considered suitable for use as fuel for high speed, compression ignition engines is something like 430° on the initial to 680° on the endpoint. To limit the cut from the fractionating tower to these specifications would mean that considerable amounts of the gas oil cut would go to stove distillate on one end and to straight run bottoms on the other. From this cut also must come the greater part of the catalytic cracking charge stock.

When wholly devoted to the latter duty the volume is likely to be considerably greater by the amount of heating oil normally in the crude plus the fraction from 680° to, say, 800°, which, with most crudes, represents about the limit of recovery by atmospheric distillation. To those who so blithely predict a "revolution in oil" because of the diesel engine and catalytic cracking, it is suggested that a realistic view of supply and demand of fuel for one and suitable charge stock for the other be taken.

In surveying potential markets and products to satisfy them, it will be interesting and instructive to look a bit further into one angle that affects the quality of a diesel fuel and is not generally and completely understood. First, it should be realized that the burning qualities sought in a fuel for a compression ignition engine are exactly opposite to those that make a gasoline of good octane number. This will be easier to understand if one will conceive that the entire fuel charge for the gasoline engine enters the cylinder before compression and ignition; therefore it is advisable to retard the combustion of the air-gasoline mixture enough to avoid the trouble caused by the blow of too-quick burning. With the modern, liquid-injection, 2-cycle diesel engine, the combustion air only enters the cylinder on the suction stroke, and is compressed on the up-stroke to high pressure and consequent high temperature. At a point just ahead of total compression the ignition of the fuel begins and is progressively ignited and burned. Obviously, it is of advantage to have a fuel that will ignite and burn under the conditions of more or less vitiated air caused by the combustion of the earlier part of the fuel charge.

It is an inherent characteristic of many naphthenic base crude oils that the straight-run gasolines from them are relatively high in clear octane number and display good lead susceptibility. The reverse is true of most paraffinic base crudes but these provide the diesel fuels with better ignition qualities. The same reasoning is to be used to account for the unsuitability of a cracked stock for diesel engine fuel. The standard method of test for ignition quality of diesel fuels has the A.S.T.M. designation of D-613 - 43T and the value is called the cetane number. For tentative purposes the diesel index number is used. This is arrived at by the formula:

$$\text{Diesel index number} = \frac{\text{A.P.I. gravity} \times \text{aniline point}}{100}$$

The aniline point is a measure of the percentage of unsaturates in the oil and it will be manifest from the formula that a high aniline point (low per cent of unsaturates) with a given gravity means a high diesel index number, marking superior ignition qualities of the oil.

▼ **Vacuum distillation.** The general purpose of a vacuum distillation is, in this case, to make an additional recovery of an overhead stock above that amount that could be had by atmospheric distillation at tolerable temperatures. Or, it may be for the primary objective of obtaining a heavier bottoms product than could be obtained within suitable pressure and temperature range. In the proposition under discussion an additional recovery of overhead stock is needed as charge for catalytic cracking. The percentage thus made available is a worthwhile amount but the stock so recovered does not have characteristics of equal value with the lighter overheads. In any case, the material is of greater overall value when so used than if it were permitted to go to straight-run bottoms.

▼ **Cracking.** For as long as cracking was strictly a pyrogenic operation it was logically considered as an entirely separate process, not interrelated to any other refinery processes except treating and blending. Any attempt to consider catalytic cracking in the same light can only result in retarding its development and in wasting crude petroleum through failure to make use of its potential service units. An opportunity such as seldom comes to any industry is now here, not only to justify the reputation of skilled technologists, but further to add to the prestige refiners have as sound thinking men.

▼ **Catalytic cracking.** Catalytic cracking will be considered simply as an improvement over thermal cracking, for the overhead product has much better utilization characteristics. Catalytic cracking is not revolutionary in principle, as it has been known for a long time that contacting the vapors of cracking with certain selected clay type catalysts was effective in improvement of some characteristics of the product. The action seemed to be largely adsorbent because the improvement was noticeable only in the first, minor part of the condensate and practically ceased upon surface contamination of the catalyst. Development of methods of reactivation of the catalyst in place can be credited with the present wide use of catalytic cracking. The problem remains largely one of economics. When the period of activity of the catalyst becomes so short, because of nature of charge stock, that reactivation apparatus reaches an unduly high cost, the process loses its economic importance. Consequently, virgin overhead stocks are now considered suitable feed material to catalytic cracking.

Note from the composite picture that there are three sources shown as supplying feed stocks to catalytic cracking. These are: Some part, or all, of the specification diesel cut, as operating or market conditions warrant; the gas oil

*R. G. Lovell, who was development engineer for Hancock Oil Company of California and a well known writer of technical works, died June 15, 1944, in Long Beach, California.

whose endpoint is beyond diesel specification, and the overhead from the vacuum distillation of atmospheric tower bottoms. These three together may run up to 20 per cent or more, of the crude charged to atmospheric distillation.

▼ **Partial hydrogenation and viscosity breaking.** Observe further that there is another line—16—shown as handling an overhead from a hydrogenation unit and line 29 conveying the residue from a reforming unit to catalytic cracking charge. Experience has demonstrated that, with charge stock of the general nature of the first three mentioned, a recovery of high octane gasoline of around 50 per cent of charge can be maintained on a once-through basis. When recycling is practiced the catalyst activity period usually is so shortened as to reduce the total output of gasoline per unit of stream time or to necessitate a greater number of chambers. Neither of these evils need be accepted.

Hydrogenation will not be presented as a practicable process currently for the production of gasoline. Of course, all cracking necessarily involves dehydrogenation. After having fractionated out that part of the cracked overhead that is within the range of the gasoline specification, a substantial amount of overhead stock, too heavy for gasoline, is left, but is still not a heavy residue. To subject this stock to what might be called a "mild" hydrogenation without attempting to produce gasoline directly from it would inevitably return some portion of it to approximately the same molecular structure as the virgin stock whence it came. Much research work is being done in this matter and tangible results may soon be available. Note that the hydrogenation unit is shown as being charged, not only with the cracked gas oil from the catalytic cracker, but also a side cut from the vis breaker is being offered for hydrogenation.

The writer is firmly of the opinion that the difficulties of satisfactorily treating the cracked gasoline from a heavy bottoms charge stock are so great that more hope of using it efficiently lies in hydrogenating it, followed by catalytic cracking, than in trying to treat it in the conventional way with sulphuric acid. This idea is furthered by the prevailing tendency in bunker fuel oil specifications. The tendency is constantly toward lower viscosity. This makes the production of cracked gasoline from straight-run bottoms secondary to production of specification fuel oil. Bottoms from hydrogenation are shown in line 37 as going to distillate fuel oil. This is entirely conjecture. As the idea is worked out it may be found that the residue will have other and more profitable uses.

▼ **Thermal cracking.** Cracking by heat alone has by no means lost significance. It has been largely supplanted by catalysis for production of superior quality of gasoline, but it will still serve as a necessary auxiliary to the complete processing of oil. It can be made use of to crack all or a part of the gas oil cut from catalytic cracking and produce charge stock for hydrogenation, cracked naphtha for reforming or treating by conventional means, and fuel oil, or it can be so operated as to increase very substantially the amount of gases available for alkylation, or for butadiene, or for many other purposes. In other words, as an auxiliary it becomes a versatile process whereas as a primary process it has a multitude of faults, and is far from flexible in operation.

▼ **Stabilization.** This process was considered as more or less of a necessary evil in a refinery until the demand for alkylation charge stock brought it into a more prominent position. Stabilization of crude oil has been practiced for years, chiefly to reduce evaporative losses in storage, and refineries have used it for reduction of hydrogen sulphide from cracked stocks and reduction of vapor pressure of light straight-run naphtha.

The demand for all possible recovery of both isoparaffins and selected butylenes for alkylation changed the objective of stabilization and greatly enlarged its usefulness and importance. Whereas before the advent of alkylation, stabilizing to vapor pressure left a substantial part of the C_4 in the bottoms, now full recovery of the butanes and butenes reduces the vapor pressure of stabilizer bottoms to such a point that blending up to volatility is required. This can often be accomplished by using part of the normal butane from which the isobutane has been separated.

Lines 23-24 and 20 show some of the sources of cracked vapor charge to the stabilizer. Some isobutane is recovered from these vapors along with the butylenes, but the major part of the needed isoparaffins would come from the natural gasoline plant, the crude distillation, and light straight-run naphtha storage. The stabilizer overhead would go to methane-ethane and to propane.

▼ **Reforming.** Reforming is simply an auxiliary cracking operation, preferably performed by catalysis, in which the feed stock is usually a heavy, straight-run naphtha. The purpose is entirely to raise the octane number of the stock to a level that will make it a suitable blending material for motor gasoline. The process is successful although the recoveries of higher octane material are not great. With the more complicated, but better balanced, refinery processing of today and tomorrow, reforming will probably be used in many set-ups where the general plan is simple in objectives.

▼ **Hydroforming.** Hydroforming is a catalytic process that has as its general purpose the aromatization of heavy paraffinic naphtha. The process may be used simply for octane number improvement but, when operated on selected stocks and under special conditions, can be used for production of toluol and other aromatics. One of the advantages of making toluol from petroleum is that the charge stock is normal heptane with a zero octane number. This makes the heptane hydrocarbon of negative value in a gasoline blend.

To segregate it for this reason alone, however, would cost more than its removal would be worth. It is interesting to note that the rather recent development of the "rich mixture" aviation gasoline for use in sudden demands for maximum power is based principally upon a superaddition of aromatics. The production of 70-90 per cent of the theoretical yield of toluol from normal heptane has been reported. When operated for octane number improvement, yields of 80 per cent of 80 octane gasoline are generally expected from a heavy naphtha feed stock of around 40-45 octane.

▼ **Alkylation.** The official technical definition of alkylation is about as clear as a current income tax form. It will suffice for the present purpose to define it as a process wherein approximately equal molecular weights of isobutane and selected forms of the butylenes are brought into intimate contact in the presence of a catalyst, with the end product showing a molecular weight equal to the sum of the mol weights of two components and an octane number equal to the average of the two. Neither of the components of the charge stock can generally be used as an engine fuel because of high vapor pressure. Both are gases at ordinary temperatures. It will, therefore, be obvious that alkylation makes a valuable product from raw materials that have heretofore been used chiefly as fuel gas.

It is worthwhile to consider also that alkylation is another of the many children of necessity. Some years ago aviation engineers had the problem of deciding whether to accept the gasoline offered them and devote their research work to improvement in engines or to perfect the existing type of engine and demand from the petroleum industry a fuel that would operate successfully in high compression engines, without the troublesome knocking that had retarded further increase in compression ratio. It was known that isooctane had the ability to resist the knock tendency to a great degree. To isolate this hydrocarbon from petroleum was known to be possible, but very costly. Further its volatility was too low. So, what next?

Petroleum chemists had found that when the branched chain form of butane — C_4H_{10} — was combined with the olefin unsaturate that had been partially dehydrogenated in the cracking cycle and was expressed by the symbol — C_4H_8 — in the presence of concentrated sulphuric acid, the result was an isoparaffin—C_8H_{18}—and that when this was fractionated to about 300° endpoint, and blended with proper proportions of isopentane and with a narrow cut of low endpoint, selected straight-run gasoline of low sulphur, the blend could be raised to 100 octane with the permitted amount of tetraethyl lead.

The prevailing enthusiasm over catalytic cracking as a source of aviation gasoline base stock has caused some to look upon alkylation as sort of a poor relation, or, at best, a subjunctive auxiliary to catalytic cracking. This is definitely not a true view of the situation. Let it be realized that catalytic cracking as a source of high octane gasoline depends upon the alkylation of some of its waste gases to make it attractive as an economic proposition. ★★★

White arrows show where Hycar is used in this important application. Cross sectional drawing is of the ram-type tubing head, shown in photograph at left.

Photograph, left below, shows where Hycar is used in the ram itself, the *critical* part of this tubing head.

Photographs courtesy Cameron Iron Works and Murray Rubber Company.

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The Capacitor-An Aid to Electric Power Service for Pipe Lines*

By M. A. HYDE and R. E. MARBURY†

IN the overall design of an electrified oil pipe line, power service constitutes a major problem, not only because of its importance in the economic structure, but also because it is a problem more varied in its component parts than almost any other phase of the project. Station designs are for the most part repetitive; power service facilities up to the point of delivery vary widely from station to station. In the completion of three recent major pipe line projects, power service has been facilitated in numerous instances by capacitors; in some cases under conditions imposed by wartime conservation of power service materials, capacitors have been the key to successful station operation.

▼ **Power service to pipe line pumping stations.** Trunk oil pipe lines of today range in size up to 24 in. diameter and in length up to 1400 miles. Such are the dimensions of the line popularly known as "Big Inch" now under completion to carry 300,000 bbl. of oil per day from Texas to the Atlantic Seaboard. In usual modern trunk line practice the task of propelling the oil through the pipe is performed by centrifugal pumps in stations at intervals along the line with 1, 2, or 3 pumps operating in series in each station. In the major pipe line projects of the last several years these pumps are driven by electric motors of the squirrel cage induction type, in ratings ranging up to 1500 hp. per unit.

The installed motor capacity on a large line totals as much as 131,000 hp. in the case of Big Inch of which 126,000 hp. is applied to main-line pumping. Data on motor capacity, units per station, average spacing of stations and number of stations are given in Table 1 for 3 major lines.

From this table it is readily appreciated that power service is a large factor in pipe line design, and with load factors well above 90 per cent the rule, power cost is an important item in operating expense. As an indication of just how important, the annual power bill for operation of the Big Inch line will be some $6,000,000.

The whole character of pipe line operation, and in turn of power supply stems from subdivision into stations separated geographically but joined physically. Reference may be made to a discussion presented elsewhere[1] of the hydraulic conditions determining station spacing and location. To summarize briefly here:

For a given condition of pipe, fluid, and rate of flow, the friction pressure drop per mile is fixed. Interchangeability of pumping equipment requires that the station incremental pressures be uniform. Under these conditions the station sites are quite rigidly determined by the profile of the line without appreciable flexibility. In regard to power service then, station locations cannot be chosen to facilitate line construction; rather, power service must be extended to station sites as determined by pipe line hydraulics.

In planning power service, consideration must be given, of course, to both the maximum running load and to voltage conditions incident to motor starting. Fortunately from the standpoint of power supply, on the larger pipe lines employing the higher total horsepowers per station, it is economical to divide the load into as many as 3 units. This results in a much more advantageous ratio of motor starting current to running current than exists in a single-unit station.

▼ **Capacitor applications on the war emergency lines. The 24-in. line** has in general, three 1500-hp. motors per station, each with a full load input of 1285 kva. at .92 power factor, or 1181-j501 kva. Starting current per motor is 1500 amp. (locked) at .22 power factor, or 1318-j5840 kva. at 2300 volts. Total running load per station is 3546-j1503 = 3860 kva. The demand with 2 units in operation and the third motor starting at full voltage is 3682-j6844 = 7770 kva., or about 200 per cent of station full load kva. A number of stations employ reduced voltage starting by autotransformer, the demand during starting being then, with 80 per cent tap starting voltage, about 3208-j4740=5730 kva., or 150 per cent of station full load kva. Fig. 1 is a typical view of motors and switchgear in one of the 24-in. line stations.

The 20-in. line has in general, three 1250-hp. motors per station, each with a full load input of 1050 kva. at .93 power factor, or 986-j394 kva. Starting current per motor is 1480 amp. (locked) at .24 power factor, or 1370-j5730 kva. at 2300 volts. Total running load per station is 2958-j1182 = 3180 kva. and the demand with 2 units in operation and the third motor starting at full voltage is 3342-j6518 = 7320 kva., or 230 per cent of station full load kva. With 80 per cent tap starting voltage, the demand during starting of the third unit is 2849-j4448 = 5280 kva., or 170 per cent of station full load kva.

Since the ratio of starting demand to full load running demand is not excessive in these stations, the use of capacitors is directed primarily to improving the running load power factor to facilitate carrying the station loads with minimum reinforcement of existing facilities.

On the 24-in. line capacitors are employed at 3 station sites. In each case the total station bank is divided into 3 sections, as indicated in Fig. 2. Each section is associated with one motor, and is equipped with an electrically operated circuit breaker controlled to switch on and off simultaneously with the corresponding motor. Two of the stations have each three 720-kva. sections, and one station three 360-kva. sections. Each 720-kva. section operates in combination with its motor at full load, with a slightly leading resultant power factor, making 219 capacitive kva. available to the power system. Each 360-kva. capacitor section operates in combination with its motor with a slightly lagging resultant power factor, drawing 141 reactive kva. from the power system.

On the 20-in. line a similar arrangement of capacitors is employed at 4 stations, 2 stations having each three 720-kva. sections and two having each three 360-kva. sections. Here each 720-kva. capacitor and motor combination delivers 326 capacitive kva. to the power system; each 360-kva. capacitor and motor combination draws a net reactive kva. of 34.

Each capacitor section is equipped with an overvoltage relay to trip the capacitor breaker in case of overvoltage due to self-excitation of the associated motor.

A 120-mile 110-kv. transmission line along the pipe line right-of-way will serve three station sites common to the 24-in. and 20-in. lines. In addition to capacitors at 5 stations at these 3 sites, 2 sections of 1260 kva. each are applied

TABLE 1

Line	Plantation*			War Emergency	
Fluid handled	Refined products			Refined products	Crude
Pipe size, in.	12	10	8	20	24
Bbl. per day capacity	90,000	63,000	30,000	235,000	300,000
Approximate length	432	357	165	1550	1400
Total stations	14	14	4	20	28
Average station spacing, miles	30.8	25.5	41.1	52.5	52.5
Pumps per station	2	2	1	3	3
Pump motor hp. per unit	900	600	600	1250	1500
Total motor hp. installed on main pumps	26,100	17,400	2,400	108,350	126,000
Number companies supplying power	10 for total line			16	17

*Data for main line only, Baton Rouge, La., to Richmond, Va. Total mileage including branch lines 1425, total station 35.

*Presented before American Institute of Electrical Engineers, New York City, January 24-28, 1944.

†Hyde is industry engineer of the petroleum and chemical section, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania, and Marbury is engineer in the capacitor section of the same company.

[1]Bibliography at end of article.

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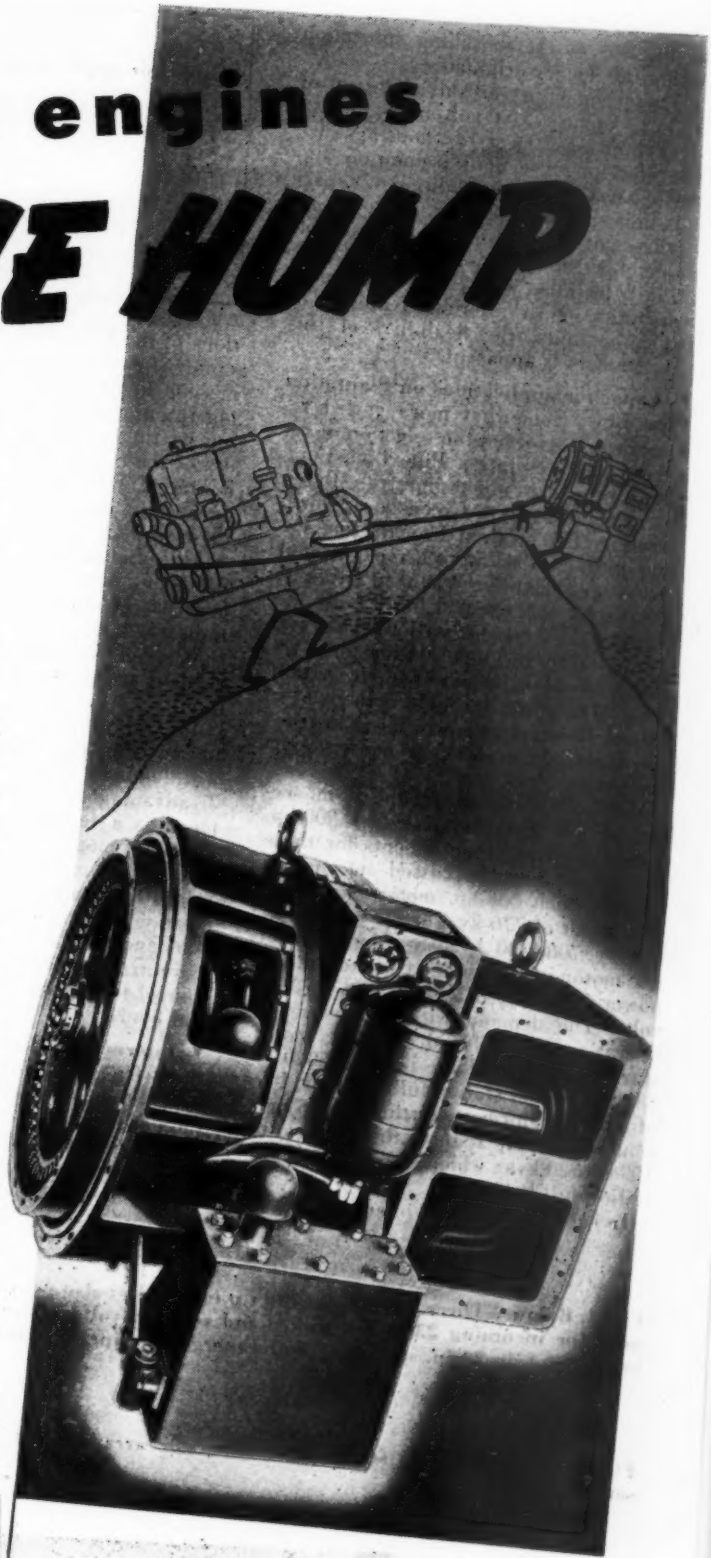

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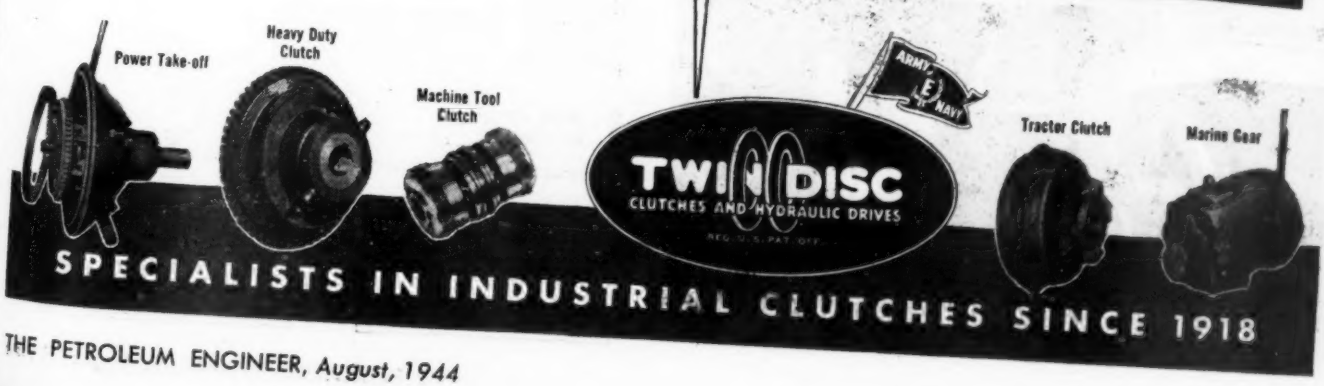


SPECIALISTS IN INDUSTRIAL CLUTCHES SINCE 1918

at the bus of the switching substation where this feeder originates.

These capacitors are all made up of 15-kva. 1-phase 2400-volt units in outdoor housings. Oversize housings are provided for all sections at pumping stations, permitting later addition of capacitor units if desirable. Fig. 3 shows one of these outdoor housings built to accommodate a 1080-kva. capacitor section, initially installed with 720 kva. of capacitor units. With interchangeability of capacitor units, the flexibility of this arrangement is apparent.

▼ Capacitor applications on Plantation Pipe Line. Somewhat more varied requirements governed the selection of capacitors on Plantation Pipe Line Company's refined products line from Baton Rouge, Louisiana, to Greensboro, North Carolina. The original 14 main line stations built in 1941 were served without particular difficulty. When an increase in capacity was effected in 1942 by the addition of 14 booster stations, however, a number of the new station sites required considerable power service extensions. Meanwhile the development of a critical situation in power line construction materials made their conservation imperative.

Each of the stations on the 12-in. section of the line contains two 900-hp. motors. Starting requirements for these units have been discussed in another paper.[2] Each 900-hp. motor has a full load input of 776 kva. at .91 power factor, or 706-j320 kva. Starting current per motor is 1200 amp. (locked) at .17 power factor, or 815-j4700 kva. at 2300 volts. The demand with one motor in operation at full load and one motor starting at full voltage is 1521-j5020 or 338 per cent of station full load kva. Use of autotransformer starting on 85 per cent voltage tap reduces this demand to 1296-j3720 kva., which is 254 per cent of station full load kva.

In each of the 7 new intermediate stations of the 12-in. line, it was found that shunt capacitors would conserve transmission line capacity either by enhancing running power factor or by improving starting conditions to facilitate delivery of the required starting voltage. Cooperating with the power company in each case, capacitors were installed in these stations as shown in Table 2.

TABLE 2

Capacitor applications—Plantation Pipe Line 12-in. line intermediate stations

Station	Installed C kva.	Number capacitor sections	Operation	Method of Control
Fluker	1080	1	intermittent	Energized only during starting of either motor.
Hathorn	810	2	continuous	Both sections energized during operation of either motor.
Paulding	225	1	continuous	Energized during operation of either motor.
Boyd	1260	2	continuous	Each section energized during operation of associated motor.
Coaling	630	1	continuous	Energized during operation of either motor.
Vincent	630	1	continuous	Same as Coaling.
Heflin	630	1	continuous	Same as Coaling.

All sections consist of 15-kva. 1-phase 2400-volt units, except Fluker which consists of 15-kva. 1-phase 1750-volt units.

Views of the equipment in one of these stations are shown in Figs. 4 to 7, inclusive.

In two of these stations where the power company installed transformers with load tap changers, as shown in Fig. 7, advantage was taken of this equipment as a further means of providing adequate motor starting voltage, by arranging the motor control automatically to run the tap changer to the full boost position in preparation for each motor start and then at completion of the start to return the tap changing mechanism control to its own voltage relay for normal operation.

▼ Intermittent capacitor at Fluker station. The capacitor application at Fluker station is of special interest. Under the power rate schedule applying to this station there would be no return to the pipe line for operation at power factors higher than the normal running values attained by these units; consequently the capacitor is employed for improvement of starting conditions only.

The station is served over a 23-kv. circuit of No. 2 copper, 17 miles long, having an impedance, including stepdown transformer at the pumping station, of

(*Continued on Page 87*)

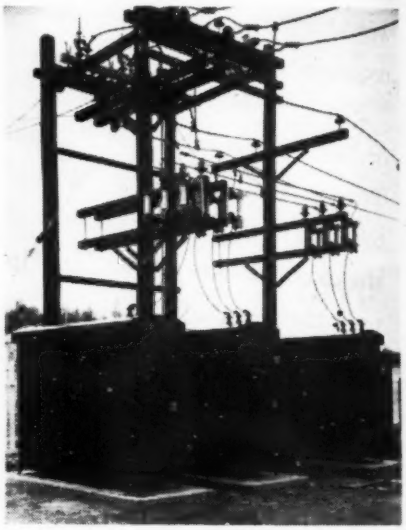


Fig. 3. Outdoor capacitor installation as used at certain War Emergency Pipeline 24-in. and 20-in. line stations.

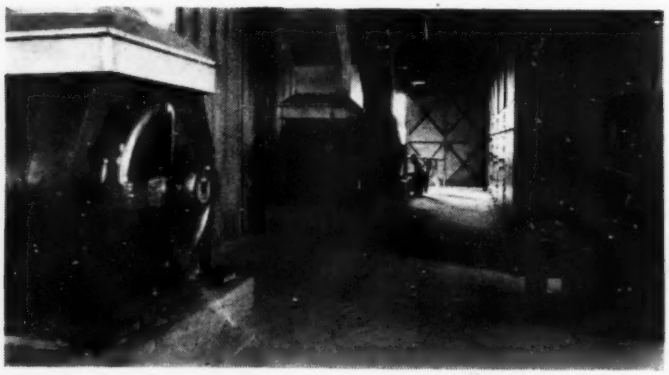
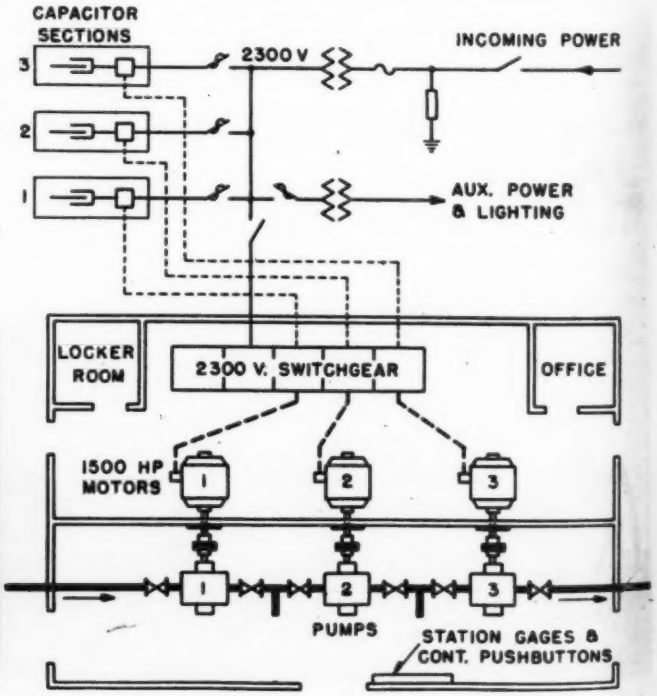


Fig. 1. Below—Three 1500-hp., 1780 r.p.m. motors; also switchgear for incoming 2300-volt power and reduced voltage starting control, in 24-in. station of War Emergency Pipelines, Inc.

Fig. 2. Right—Power service and capacitor arrangement in same station.



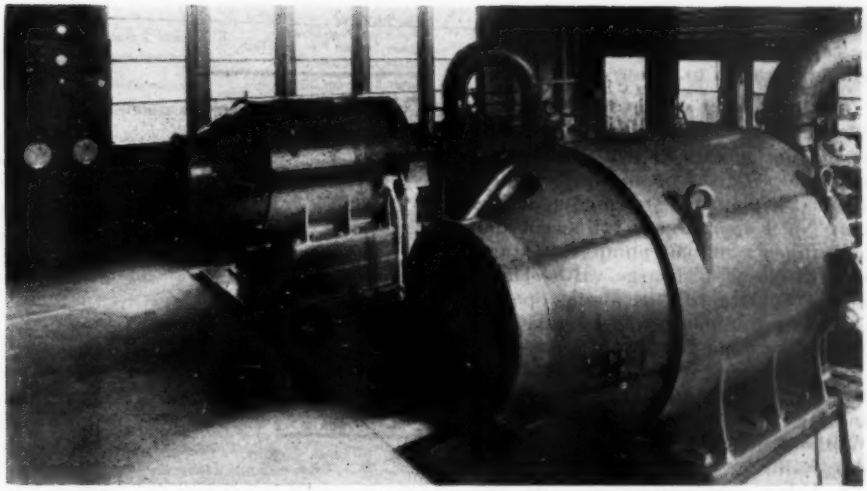


Fig. 4. Above—Two 900-hp., 3585 r.p.m. motors driving 12-in. products line pumps, in intermediate station of Plantation Pipe Line. Fig. 5. Left—Switchgear for control of 2300-volt incoming power breaker, two 900-hp. reduced-voltage motor starters, auxiliary low-voltage power and lighting. Control panel for single-section capacitor at extreme left. Plantation Pipe Line.

(*Continued from Page 82*)

approximately 0.183 + j.387 ohms per phase. With one pump unit operating at full load and the second unit starting on 85 per cent autotransformer tap and at 2750 r.p.m., critical speed from standpoint of motor torque margin, the current demand is 320-j780 amp. at 2300 volts. This combination of line and load impedance indicates a voltage at the station bus of about 78 per cent of the sending voltage, a value inadequate to provide reliable starting.

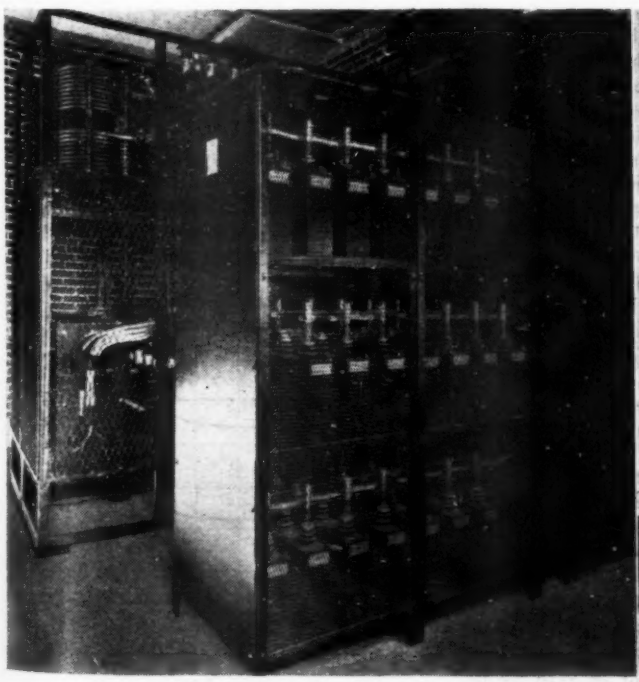
It was decided to apply sufficient capacitor to reduce the current during starting to a value of 320-j315 amp. at 2300 volts. The resulting station bus voltage was calculated as about 88 per cent of the sending voltage.

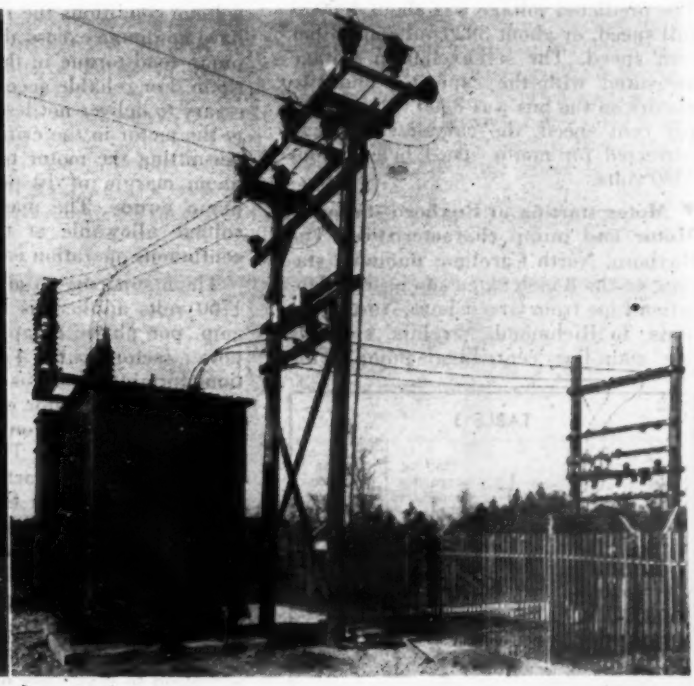
The corrective current of this capacitor, 465 amp. at 2300 volts, corresponds to a rating of 1860 kva. To conserve materials and capacitor cost, an intermittent capacitor was designed for starting duty only. This was accomplished by employing units continuously rated at 1750 volts, operated at 120 to 137 per cent of rated voltage during starting. This capacitor, rated 1080 kva. at 1750 volts, provides the same corrective effect as would a standard 2400-volt 2030-kva. capacitor, representing a saving of 950 kva. or 47 per cent in applied capacitor kva.

The capacitor was installed as a single section switched by electrically operated circuit breaker. Its control is combined with the control of the two 900-hp. pumping motors so that when either motor is started the capacitor is connected simultaneously to the station bus until the completion of the starting period when it is automatically tripped by an auxiliary relay operated by the motor starter.

Comparison of the no load saturation curve of the motor with the capacitor volt-ampere line indicated a possible self-excitation voltage of about 4000 volts in case of service interruption with the capacitor and one motor at full speed on the bus, and about 3500 volts with the capacitor and two motors, one running and the other just completing a start[3]. An overvoltage relay therefore was in-

Fig 6. Left—Rear view of equipment shown in Fig. 5, capacitor in foreground. Fig. 7. Right—Minimum use of substation construction materials features this substation with completely self-protecting transformer. Plantation Pipe Line.





cluded in the capacitor control, to trip the capacitor breaker limiting the overvoltage duration to a few cycles.

▼ **Tests at Fluker station.** Oscillograph tests were made at this station to check the starting performance of the installation. Table 3 gives comparative results with and without the starting capacitor, pump No. 1 operating at full speed and about 76 per cent load, pump No. 2 starting with closed discharge valve. These tests were made with the pumps operating on kerosine of specific gravity 0.80, a condition imposing about 8 per cent lower pump load torque during acceleration than the maximum design condition handling 0.867 specific gravity fuel oil.

Without the aid of the capacitor, the voltage during starting dropped to a value below that permissible with the line handling fuel oil, although the unit did start successfully handling kerosine.

This test was made with the motor starting on 80 per cent autotransformer taps, a condition imposing about 89 per cent of the demand that would be developed using 85 per cent taps, which latter condition was the basis of design of the capacitor installation. Calculation of voltage conditions with motor No. 1 running and motor No. 2 starting on 80 per cent autotransformer taps, indicated a bus voltage of 79.8 per cent of sending voltage with the capacitor in service. The tests results are in good agreement with these values. Sections of the oscillograms for these tests are shown in Fig. 8.

Tests were also made to measure the self-excitation voltage obtained with this combination of motors and capacitor. In each case the incoming line breaker was tripped with the motor (or motors) and the capacitor connected to the bus, the motor at full speed and pump discharge valve closed, a condition developing about half load on the motor.

The self-excitation voltage measured with the capacitor and one motor was 3760 volts at 98 per cent motor speed. The predicted voltage was about 4000 at full speed, or about 3920 volts at 98 per cent speed. The self-excitation voltage measured with the capacitor and two motors on the bus was 3200 volts at 96.5 per cent speed, the calculated voltage corrected for motor speed being about 3380 volts.

▼ **Motor starting at Roxboro station—Motor and pump characteristics.** The Roxboro, North Carolina, pumping station, on the 8-inch extension of the Plantation Line from Greensboro, North Carolina, to Richmond, Virginia, contains one main-line centrifugal pump. This

TABLE 3

	Starting capacitor inoperative	Starting capacitor operative
Accelerating time for pump No. 2, seconds	20.5	12.8
Bus voltage		
Before starting pump No. 2.	2190	2160
With pump No. 2 at 2750 r.p.m.	1775	2015
Both pumps at full speed capacitor energized	....	2370
Both pumps at full speed, capacitor disconnected	2100	2070

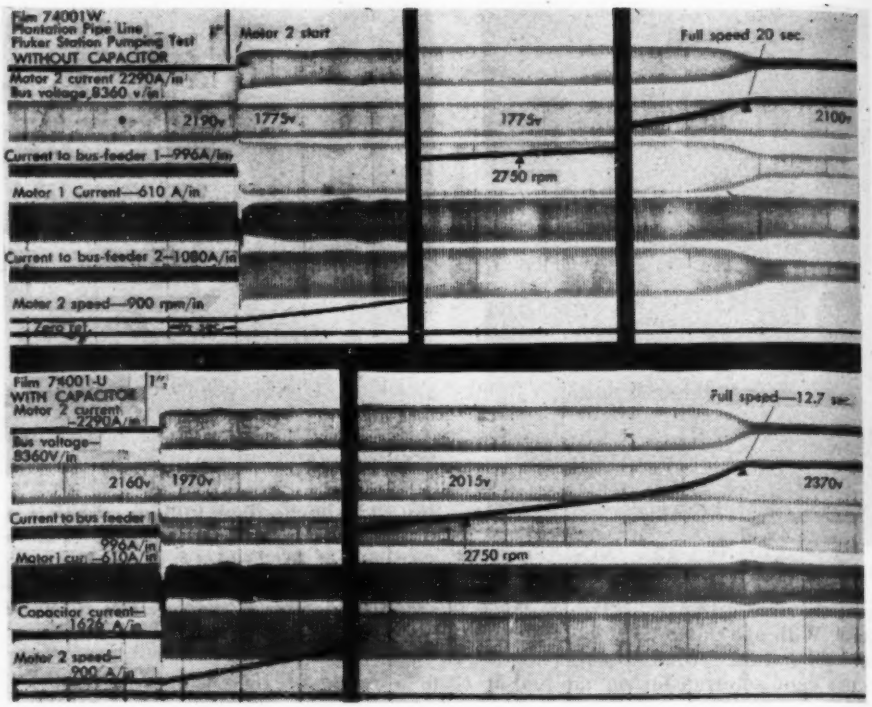


Fig. 8. Sections of oscillograms showing starting performance of 900-hp. pump motor, Fluker station test.

pump is coupled to a squirrel cage motor, rated 600 hp., 3586 r.p.m., 2300 volts, 3 phase, 60 cycles. Full load input is 131.2 amp. at 0.91 power factor or 417-j219 kva. The motor is started on full voltage. Locked rotor current at 2300 volts is 823 amp. at 0.17 power factor or 558-j3240 kva. This is 626 per cent of full load kva.

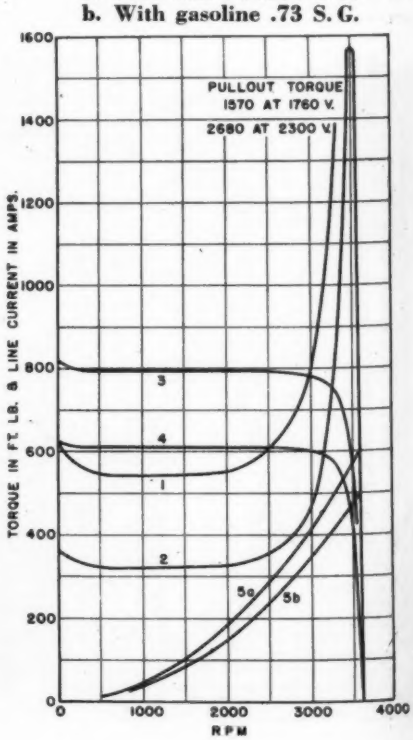
The motor has speed-torque and speed-current characteristics by test as shown in Fig. 9, curves 1 and 3. Curve 5a shows the speed-torque curve of the pump when started with discharge valve closed, when handling fuel oil of 0.867 specific gravity, heaviest product anticipated. Comparing the motor speed torque with the pump speed torque curve, it is evident that under reduced voltage conditions the motor torque will have minimum excess above the required pump load torque in the region of 2800 r.p.m. For reliable acceleration it is necessary to deliver not less than 1760 volts to the motor in the critical speed range, permitting the motor to develop a minimum margin of 10 per cent over the pump torque. The maximum sustained voltage allowable at the motor under continuous operation is 2530 volts.

The motor current at 2800 r.p.m. with 1760 volts applied, is by shop test 603 amp. per phase, at approximately 0.20 power factor (curve 4). In the calculations forming the basis of application, a slightly higher motor current was used, obtained from tests on a motor of similar characteristics. This current, 658 amp. at 0.20 power factor, for 1760 volts 2800 r.p.m. is within the range of manufacturing variation that may be encountered on individual motors of the same design.

▼ **Conditions of power service.** In serving this pumping station it was necessary in the interest of line materials conservation to make use of an existing 12-

Fig. 9. Starting characteristics of 600-hp. drive on 8-in. products line.

(1) Speed-torque for motor at 2300 volts.
(2) Speed-torque for motor at 1760 volts.
(3) Speed-current for motor at 2300 volts.
(4) Speed current for motor at 1760 volts.
(5) Speed-torque for pump starting with closed discharge:
a. With fuel oil .867 S. G.
b. With gasoline .73 S. G.



kv. power line of No. 2 copper from the power company's 7500-kva. 132/12.4-kv. substation to a point about 16.4 miles distant, where a new tap line of No. 2 copper extends about 3 miles to the pumping station site.

The total impedance of the supply to the 2400 volt bus at the pumping station is approximately 0.745 + j.875 ohms per phase referred to the 2400 volt bus.

▼ **Starting voltage without corrective means.** From the motor impedance at 1760 volts and the total impedance of supply, the calculated starting voltage at the motor, assuming a sending voltage of 2530, and no other load on the feeder, is 1388 volts. This is below the minimum allowable voltage for starting the motor. Alternative service facilities were considered, but were not permissible from the standpoint of critical materials conservation.

▼ **Capacitor requirement.** The power company agreed to serve the pumping station over this circuit and to deliver a minimum voltage of 1760 during starting, provided Plantation install a two-section capacitor at the pumping station bus[4]. With both sections energized during starting of the pump motor, the total bank was required to provide a capacity effect of 1185 kva. at 1760 volts. In arriving at this value of capacitor, it was assumed that simultaneously with the motor starting demand there would also exist on the feeder 80 per cent of the distribution load, or 355 kw. at 0.80 power factor.

After completion of the motor starting period, one section is switched off, leaving an effective capacitor kva. of 650 at 2530 volts, this being the calculated voltage attained with this capacitor and the motor running at full rated load, and with 20 per cent distribution load. The capacitive kva. of 650 at 2530 volts was developed by applying a standard 2400-volt capacitor of 585-kva. rating (-j9.85 ohms per phase, line to neutral) as the continuous running capacitor section.

Since the required total effective capacitive kva. at 1760 volts must be 1185 kva., of which 315 kva. are obtained at this voltage from the continuous running capacitor, the difference or 870 kva. at 1760 volts must be provided by the second capacitor section. This section, being in service only during starting of the motor, was designed for intermittent operation.

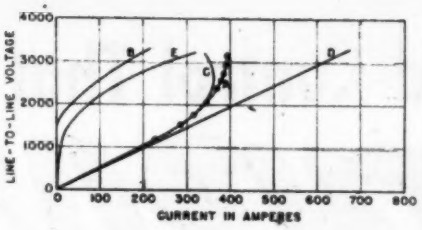


Fig. 11. Test volt-ampere characteristic curves for capacitor-autotransformer combination. Capacitive reactance = —j2.83 ohms.
(A) Total current input to combination.
(B) Power component current.
(C) Wattless component current.
(D) Capacitor current (input side).
(E) Autotransformer magnetizing current (D-C).

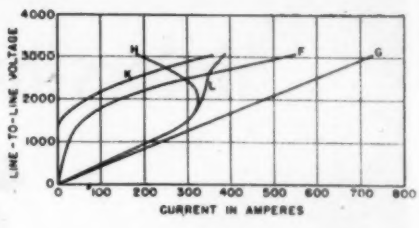


Fig. 12. Calculated volt-ampere curves for combination of standard 2400-volt capacitor and double autotransformer. Capacitive reactance = —j2.44 ohms.
(F) Autotransformer magnetizing current (2E).
(G) Capacitor current input side.
(H) Wattless component current (G-F).
(K) Power component current (2B).
(L) Total current input to combination (K-jH).

▼ **Feeder voltage regulation as affected by capacitor.** Investigation indicated that application of a capacitor as large as 1185 kva. at 1760 volts for starting conditions would introduce a critical problem of voltage regulation. At the end of the motor starting cycle, when the motor approaches full speed, its starting current suddenly decreases to a low value, leaving a large net capacitor current on the bus until the starting capacitor can be tripped off. This results in an increase in voltage at the bus, which in turn increases the capacitor current and this further increases the voltage, the condition stabilizing at a value calculated as about 3200 volts, a value undesirably high.

Consideration was given to the possibility of reducing the peak voltage by relaying responsive to change in motor power factor or impedance, to trip the starting capacitor breaker as soon as the motor reaches a speed where this capacitor is no longer necessary. However the capacitor is required until the unit is well up to full speed, after which acceleration is extremely rapid, due to the low inertia of the motor and pump and the suddenness with which the motor torque increases after passing the critical range. While such relaying would serve to limit the duration of overvoltage to within a fraction of a second, it will be borne in mind that this overvoltage would occur each time the motor is started. This condition was undesirable from the standpoint of service to the pipe line and to other customers on the line.

▼ **Method of limiting line-regulation voltage.** The problem thus devolved into finding a means of preventing the occurrence of this overvoltage. The attack was to devise a way of neutralizing the increase in capacitor current inherent with increase in applied voltage.

The solution was effected by providing in opposition to the capacitor, an inductive reactance suitably controlled throughout the starting cycle. Such control implies a small reactive current at the low voltage existing during most of the starting period, but a large reactive current when the voltage increases near the end of the starting period, to balance the excess capacitor current at the higher voltage. One method proposed for accomplishing this control was use of an iron core reactor designed to saturate at a voltage slightly above that at which the capacitor effect is primarily desired.

(*Continued on Page 94*)

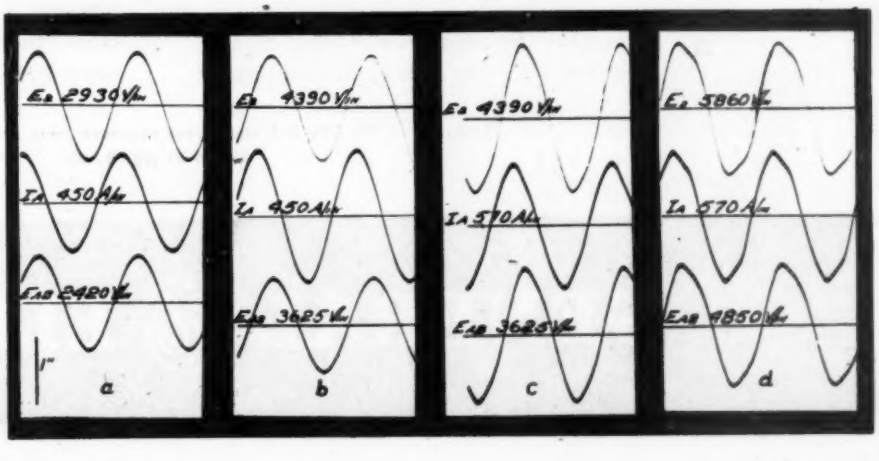


Fig. 10. Oscillograms from combination test of autotransformer and capacitor.
E_{ab} = Voltage, phase AB, applied to autotransformer (65 per cent tap).
E_2 = Voltage, phase AB, on capacitor (100 per cent tap)
I_a = Line current, phase A, on input side of autotransformer.

Test	E_{ab}	E_2	I_a
(a)	1198	1688	230=0+j230
(b)	1770	2440	314=34.7+j313
(c)	2560	3445	377=97.5+j364
(d)	3120	4140	391=188+j344

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MOTORS AND CONTROL

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(*Continued from Page 91*)

In the case of Roxboro station, an economical intermittent capacitor bank was devised by using standard 2400-volt capacitor units and connecting the bank to the station bus through an autotransformer, so as to impress upon the capacitor bank a voltage about 1.4 times the bus voltage. Thus the operating kva. of the capacitor is increased to about twice the kva. at which the capacitor would operate if connected directly to the bus.

It is apparent that the autotransformer supplying the intermittent capacitor section can be utilized to provide the necessary controlled reactive current to limit the effect of the capacitor in the upper range of voltage. To accomplish this, the magnetizing current of the autotransformer at 1760 volts should be as low as feasible, while at voltages above 2400 saturation should occur, with resultant sharp increase in lagging current.

▼ **Laboratory investigation.** To determine quantitatively the required autotransformer proportions certain tests were conducted:

1. An extended no-load saturation test was taken on a 600-hp. motor identical with the one at Roxboro pumping station. Whereas ordinary test procedure is to carry the no-load saturation test up to a voltage of about 20 per cent above rating, in this test readings were taken with voltages up to 200 per cent normal. Results are plotted in curve M of Fig. 13.

2. A series of tests was made on a capacitor bank electrically similar to the proposed intermittent section at Roxboro pumping station, in combination with an autotransformer.

The test capacitor was a 3-phase bank, delta connected, consisting of 19 capacitor units in parallel per phase, each unit being rated 15 kva., 2300 volts. The autotransformer was of the standard motor-starting type, rated 600 hp., 2300 volts, 3-phase, open delta, with voltage taps of 50, 65, 80, and 100 per cent. This unit was connected to deliver current from its 100 per cent taps to the capacitor, and to receive current on its 65 per cent taps from a large testing plant generator. To simulate line conditions at Roxboro station, a series impedance was inserted, equivalent to 0.80 + j0.90 ohms per phase on the low side.

A series of oscillograms was made, recording autotransformer input voltage and current, and autotransformer output voltage, over a range of input voltage values up to about 3100 volts. Fig. 10 shows typical oscillograms.

From these tests the following data were derived:

1. The volt-ampere characteristic curve for the combination of capacitor and autotransformer was plotted as shown in curve A, Fig. 11.

2. From each test oscillogram the input power factor was calculated and the total input current was separated into its power and wattless components. The power component values are shown in curve B and the wattless component values in curve C.

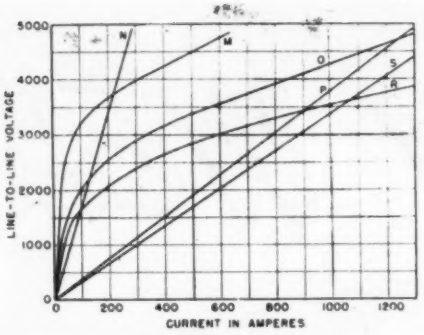


Fig. 13. Self-excitation characteristics for 600-hp. motor and capacitors.

- **(M) Excitation current for one motor.**
- **(N) Capacitor current for continuous capacitor (X= —j9.85 ohms).**
- **(O) Excitation current for one motor plus single auto-transformers (M+E).**
- **(P) Capacitor current for test capacitor plus capacitor (D+N).**
- **(R) Excitation current for one motor plus double autotransformer M+2E).**
- **(S) Capacitor current for intermittent capacitor (G+N).**

3. The net volt-ampere curve for the test capacitor referred to the input side of the autotransformer, is shown in curve D. This is a straight line, obtained by actual measurement of the capacitance of the capacitor (-j5.88 ohms line to neutral) then deducting the series reactance of the autotransformer to obtain a net resultant capacitance for the combination. The value obtained, referred to the low side of the autotransformer is -j2.83 ohms per phase, line to neutral. For a line-to-line voltage of 2400 on the low side, the corresponding current is 490 amp. Plotting these two values determines the effective volt-ampere curve for the test capacitor.

4. The reactive current (curve C) is the resultant of the leading reactive current of the capacitor (curve D) and the lagging magnetizing current of the autotransformer, hence the latter is obtained by subtracting the current values in curve C from those on curve D, giving curve E.

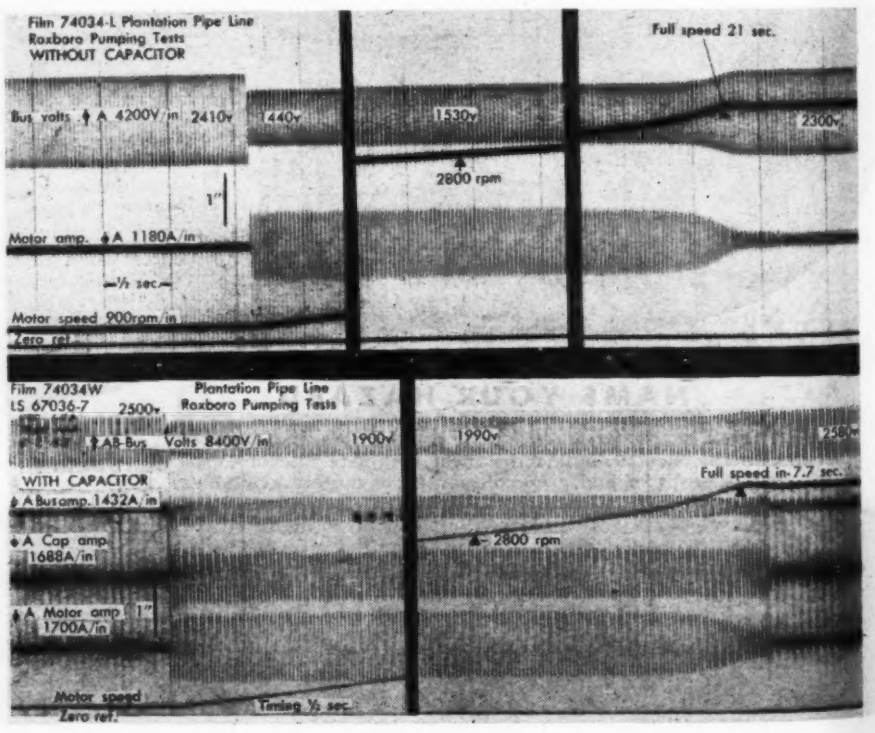
It is apparent that, with increasing voltages, as saturation occurs in the autotransformer the magnetizing current drawn by the autotransformer assumes disproportionately greater values, neutralizing to an increasing extent the capacitor current and finally, at about 2700 volts, causing a decrease in the total reactive current.

This effect of course can be increased by increasing the magnetizing current drawn by the autotransformer. In Fig. 12, curve F is a magnetization characteristic calculated for two autotransformers identical with the one tested, connected in parallel to feed an intermittent capacitor.

In this case, the capacitor consists of 78 standard 15 kva. single phase 2400-volt units, 26 units per phase.

The capacitive reactance of the capacitor bank alone is 4.92 ohms line to neutral. The series reactance of the autotransformer is now half the value previously used. The resultant effective capacitive reactance referred to the low side is 2.44 ohms, line to neutral. For a line-to-line voltage of 1760 on the low

Fig. 14. Sections of oscillograms showing starting performance of 600-hp. motor. Roxboro Station test.



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side, the phase current is 416 amp. These two values determine curve G.

At 1760 volts the magnetizing current drawn by the autotransformer bank is 98 amp., leaving a net effective capacitor current of 318 amp., or 970 bank kva. at 1860 volts. This approximates the 312 effective amperes for the test capacitor. Either capacitor bank provides about 10 per cent margin of effective capacitive current at 1760 volts, above the minimum requirement for the intermittent capacitor at Roxboro station.

Curve H is the total reactive current for the combination, and is obtained by subtracting the current values of curve F (transformer magnetizing current) from those of curve G (capacitive current.) The power component current curve K is constructed by doubling the power component currents obtained in curve D, Fig. 11, for a single autotransformer. Finally, the total current curve L is obtained by combining the power and total reactive current curves K and H.

Next, consideration was given to the self-excitation voltage possible with the capacitor banks and the motor connected to the pumping station bus, the motor at full speed and the bus isolated from the power supply by tripping of the main breaker. Two operating conditions must be considered: (1) In normal running operation the 585 kva. running capacitor will be connected to the bus with the motor; (2) during starting both capacitor banks will be in use, and self-excitation may occur with this combination at full motor speed at the end of the motor starting cycle.

Consider first the conditions obtaining during running. The maximum value of self-excitation voltage with no-load on the station bus may be predicted by finding the value at which the no-load excitation curve for the motor intersects the volt-ampere characteristic of the continuous capacitor. As shown in Fig. 13, curves M and N, this occurs at about 3750 volts.

Now considering the starting condition, the intersection of the combined magnetization curve, for the motor and test autotransformer (curve O) with the volt-ampere characteristic of the effective test capacitor plus the running capacitor (curve P) occurs at about 4750 volts. The combined magnetization curve for the motor and two autotransformers (curve R) intersects the volt-ampere line of the combined intermittent capacitor plus the continuous capacitor (curve S) at about 3600 volts. In practice these values will be decreased due to the loading effect of the losses in the autotransformer feeding the intermittent bank.

In making the capacitor application at Roxboro station, circumstances dictated use of equipment promptly available, hence it was decided to employ for the intermittent capacitor bank, the 2.44 ohm capacitor combined with two autotransformers identical with the autotransformer used in the laboratory test.

Use of two autotransformers in preference to one was for reasons of (1) sharper limitation of net capacitive current at voltages above 1760, therefore less overvoltage at the end of the starting cycle; (2) lower self-excitation voltage in case of power interruption during the starting cycle.

Standard Companies Merge

The Standard Oil Company of New Jersey has announced that it will consolidate with its wholly owned subsidiary, Standard Oil Company of Louisiana, at the end of the year. The concerns are expected to be merged under the name Standard Oil Company of New Jersey.

For this capacitor-autotransformer combination the maximum voltage on the pipe line station bus at the end of the starting cycle was calculated as 2605 volts, a value quite acceptable from the operating standpoint.

▼ **Oscillograph tests at Roxboro station.** After installation of this equipment oscillograph tests were made to check the performance of the apparatus under service conditions. During these tests, the pump was operating with gasoline, and its load torque during acceleration was thereby reduced from the values shown in Fig. 9, curve 5a, in the approximate ratio of the specific gravities of gasoline and fuel oil = 0.842. This results in a somewhat lower present speed torque curve, 5b, meaning that when gasoline is being handled a lower starting voltage is permissible on the motor. Comparison of curves 1 and 5b in Fig. 9 indicates that for zero torque margin the voltage at the motor at 2800 r.p.m. would be about 1520 volts.

A test was made starting the unit without any capacitors. The motor accelerated the pump with a very narrow margin of torque, requiring 21 seconds to reach full speed. The oscillogram showed a voltage of 1530 at 2800 r.p.m. Since the observed margin of torque is extremely small, starting performance under this condition would be unreliable. Furthermore during the major portion of the start, the voltage dropped to a sustained value of 1440 or 60 per cent of the no-load voltage, a behavior unacceptable from the standpoint of service to other customers on the line. For these reasons, regular operation without the aid of starting capacitors is impractical even when the line is handling gasoline, and would be impossible with fuel oil.

Tests with the complete capacitor installation in use showed initial starting voltage sustained values of 1870 to 1960, or 76 to 79.2 per cent of the observed bus voltages with no station load. At 2800 r.p.m. motor speed voltages ranged from 1900 to 2020. Voltages with the motor at full speed and with capacitors on the bus ranged from 2515 to 2700, exceeding by 4 to 6 per cent the observed station bus voltages with no station load.

The majority of these tests measured voltages across one phase. To check voltage balance a test was made measuring the 3-phase voltages and the results indicated bus voltage unbalance expressed in terms of maximum deviation from average as percentage of average: At no load 3 per cent, with motor accelerating 4 per cent, with motor at full speed and capacitor connected to bus 11 per cent.

It is apparent that conditions at this installation are not ideal from the standpoint of voltage balance, first because the transformer bank serving the station is made up of dissimilar units, and second because the autotransformer supplying the intermittent capacitor is of open delta construction. These conditions were necessities of the times. The unbalance inherent in the use of an open delta autotransformer can be obviated readily by employing an autotransformer of 3-phase, 3-leg construction. By special design this autotransformer also can be given more desirable saturation characteristics.

Additional oscillograph tests were made to observe the self-excitation voltage effects obtainable.

A test made with the continuous capacitor only showed a maximum self-excitation voltage on the station bus of 3360 volts, with a motor speed of 94 per cent. The corresponding self-excitation voltage predicted from curves M and N, Fig. 13, corrected to a motor speed of 94 per cent is 3370 volts.

A test made with both continuous and intermittent capacitors on the bus showed a maximum self-excitation voltage of 2910, at a motor speed of 98 per cent. The value of 3600 volts indicated from curves S and R, Fig. 13, corrected to 98 per cent motor speed, is 3520 volts.

This combination of capacitor and saturating autotransformer has been in satisfactory operation at Roxboro station since June, 1943. The scheme of control should extend the field of usefulness of the capacitor by permitting a relatively large capacitor to be used with a squirrel cage induction motor for purposes of improving starting conditions, without incurring the overvoltage effects normally experienced in such applications. Just as Roxboro station is being served over an otherwise impossible circuit, this solution should point the way to transmission line conservation in many situations involving single-unit loads in isolated locations.

▼ **Acknowledgment.** The authors wish to acknowledge the collaboration of W. E. Locher, electrical engineer, Plantation Pipe Line Company, in conducting oscillograph tests on pumping station installations.

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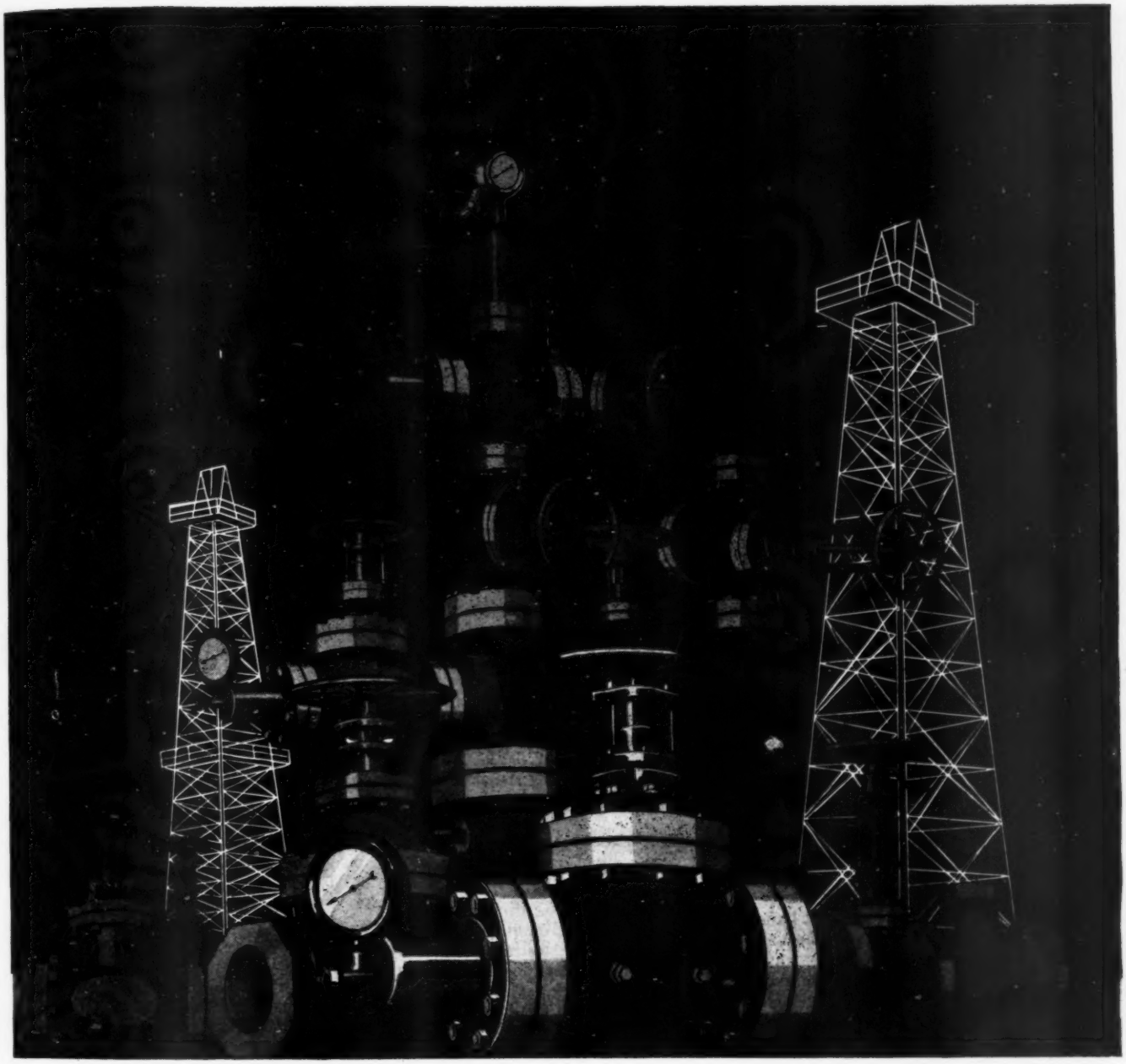

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LABORATORIES FOLLOW FRONTS

By FRANK H. LOVE

Allied petroleum products and those captured from the enemy are tested by portable equipment

EXCLUSIVE Much has been written about the importance of petroleum products to the winning of this war. It is well known that the quality of the aviation gasoline provided for the United Nations' aircraft gives our fliers a marked advantage over those of the enemy. That the fighting of a mechanized war should be an impossibility without petroleum products to fuel and lubricate trucks, jeeps, tanks, etc., is also a well recognized fact. The construction of giant refineries for the manufacture of aviation gasoline, the processes whereby this gasoline is made from crude oil, and the means of transporting the finished product to our fighting fronts, have caught the popular fancy and have been widely publicized.

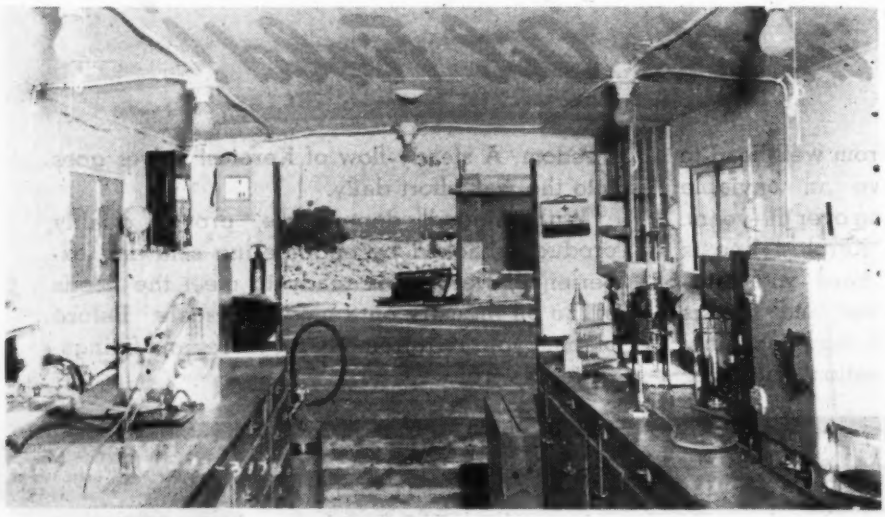
What happens to these products after they reach the fighting fronts is a story of equal interest, but one that has never been told in its entirety.

Engineer Petroleum Distribution Companies, technical organizations of the U. S. Corps of Engineers, are entrusted with the handling of products once they arrive overseas and special personnel has and is being trained to man these organizations. Insofar as is possible those selected from various branches of the army for this training are chosen upon the basis of their civilian experience in the petroleum industry.

One phase of the overseas duties of the organizations consists of constructing and operating petroleum products pipe lines, which include submarine pipe lines and port unloading facilities for discharging tankers. Their duties also include the construction and operation of tank farm terminals and pipe lines to air fields and tank and truck dispensing points near the active front. Another phase is the operation of bulk fuel handling facilities, which embraces the unloading of fuel from tankers, barges, etc., the operation of large tank farm terminals, and the batching of bulk fuel through the pipe lines. As these duties require an accurate control over products at all times, laboratory equipment and trained personnel are being provided for making the necessary tests.

▼ **Testing laboratories.** The first Engineer Petroleum Distribution Companies sent overseas during the early part of the war were equipped with petroleum products testing laboratories that were manned by specialists from the petroleum industry, selected for their skill and ability to conduct the various required tests. Sufficient laboratory apparatus, equipment, and supplies were sent with each Engineer Petroleum Distribution Company to permit a base laboratory to be established and to outfit a portable laboratory unit. The base laboratory was equipped with an octane rating engine, ice making machine, liquefied gas system, water distillation equipment, electric power generating unit, as well as apparatus necessary to perform all testing of petroleum products as required in the operation of bulk fuel handling facilities overseas. Portable laboratory units were equipped as circumstances and missions demanded, but always included a laboratory trailer, ice making machine, water distillation equipment, electric power generating unit, liquefied gas system, and apparatus for making most of the more common tests on fuels.

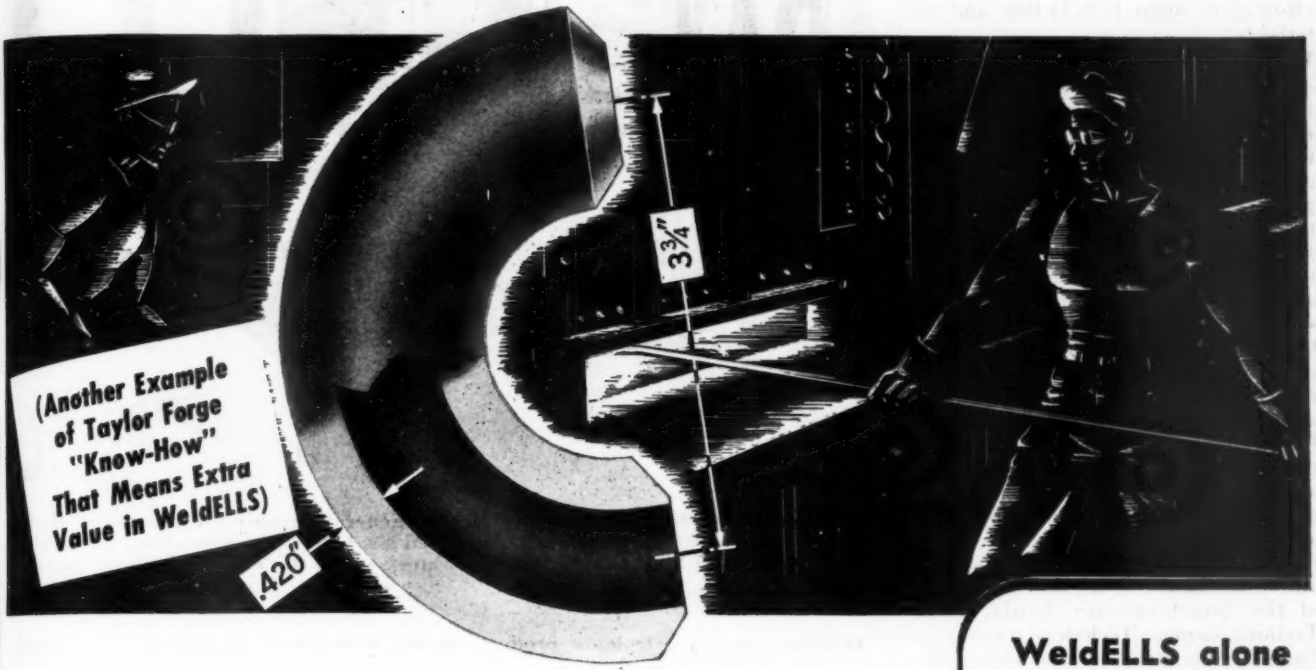
Interior view of petroleum products testing laboratory trailer looking to the rear.



Later, through coordination with the Quartermaster Corps, these laboratories were enlarged by the Corps of Engineers to include additional apparatus and equipment. These laboratories are now used by the Corps of Engineers, Quartermaster Corps, and Air Transport Command, and are sufficiently complete to make all determinations normally required in the inspection and control of oil products in theaters of operation.

▼ **Need for tests.** The need for strict testing of products is principally twofold: (1) Products whose markings have become obliterated during transportation from source to an oversea base through accidents, weather, or enemy sabotage, must be tested and identified promptly before they can be put to use, and (2) products captured from the

WHO ELSE COULD MAKE THIS?



●As far as we know, no one else ever forged a fitting like the one pictured above—or any welding elbow or return bend having a wall thickness so heavy in proportion to the size of the fitting.

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A good example of this is the selective reinforcement—extra metal properly distributed where stresses are greatest. Another is the tangents; another, the final truing operation which produces those extremely accurate dimensions. These, and the other features listed opposite, give you a better job of pipe welding at lower cost. Check over the list and we believe you will agree that

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enemy are likely to have been deliberately contaminated prior to abandonment. Moreover, if the enemy uses a product considerably different in characteristics from our own, the laboratory personnel can recommend possible uses of captured products by our forces, thus effecting economy both in time and material.

▼ **Training personnel.** Laboratory specialists having sufficient experience in industry to qualify them to conduct the required test work in theaters of operation were available for the first Engineer Petroleum Distribution Companies sent overseas, but it was realized that ultimately the Corps of Engineers would be faced with the problem of training its laboratory technicians. After a survey of possible suitable training schools the University of Tulsa at Tulsa, Oklahoma, was selected for this training. Technicians are now given training in petroleum technology at the University of Tulsa besides specialized pipe line training at Camp Claiborne, Louisiana. In addition, they are activated and partially trained at Camp Lee, Virginia. Here military training consists of a review of basic military subjects and the preparation for overseas movements and is conducted under the supervision of the Quartermaster Replacement Training Center. Technical training at Camp Lee includes lectures and discussion on pertinent phases of petroleum technology and is conducted entirely by laboratory personnel.

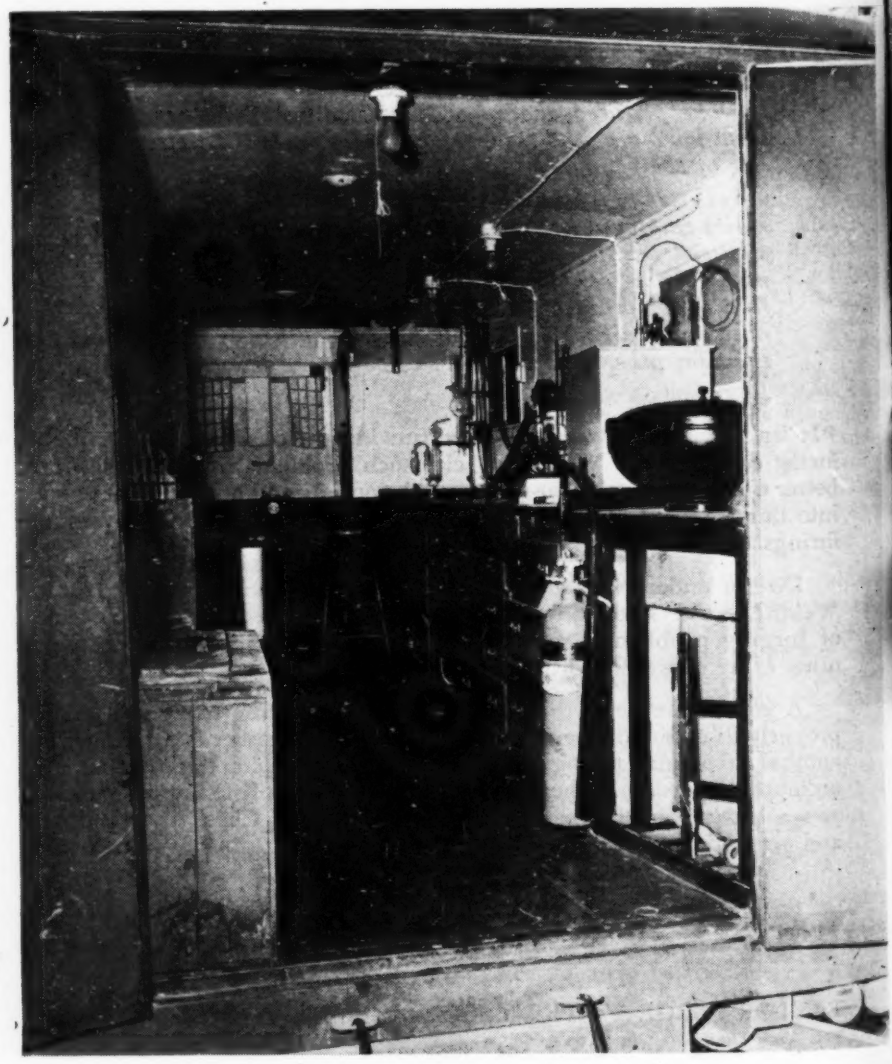
The most important phase of the technical training, however, is an intensive 6 weeks' course in petroleum technology at the University of Tulsa. The students are housed and fed by the university and spend 6 hr. a day in the laboratory, 2 hr. in lectures (petroleum and military), and 1½ hr. in study and preparation. All standard physical and analytical tests (about 60) of the ASTM and the military agencies are being taught except those that pertain to asphalt and road oil. In addition, some of the tests of the Institute of Petroleum (British) are being studied. Each test is performed four times by each student on unknown samples. The products analyzed are aviation gasoline, automotive gasoline, diesel fuel oil, combat vehicles and special lubricating oils, gear lubes, chassis greases, wheel bearing greases, water pump greases, kerosine, distillate fuel oils, and marine fuel oils.

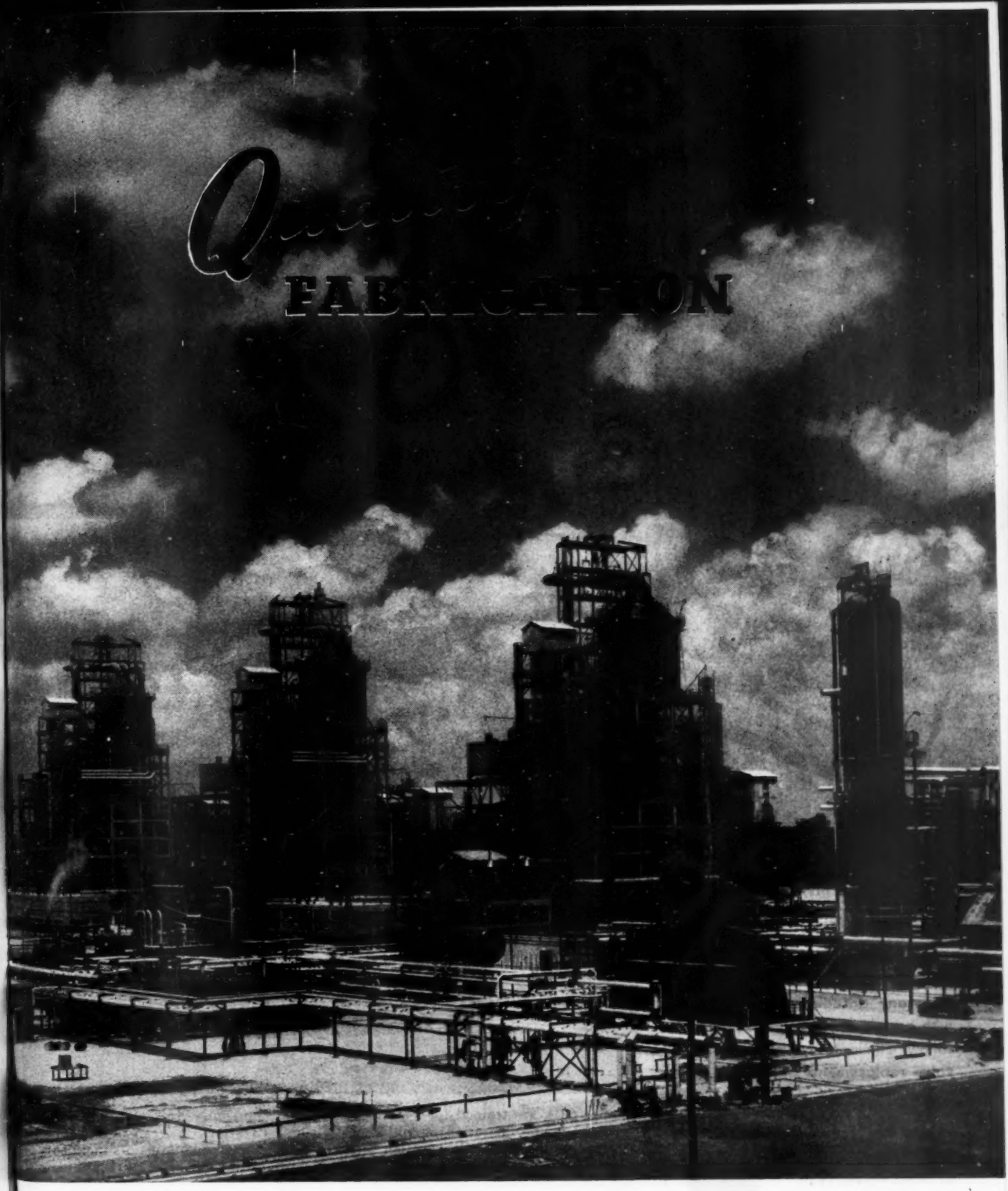
Lectures pertain entirely to the performance characteristics of each of the various products, particular attention being given to climatic and special service conditions. A mobile unit of the same type as used overseas is being used at the university, but most of the training is done in the school laboratories. Another part of the school training is actual experience in gauging, sampling, and strapping of storage tanks. This work is given at the refinery of The Texas Company in Tulsa. Students are also trained to inspect cargoes and shipments, make inspection records, etc., as well as being given detailed study of specifications of enemy products.

A limited number of students, about

Close-up of truck-tractor showing electric generating unit for laboratory trailer mounted on shortened truck bed. Liquefied gas bottles for furnishing gas to bunsen burners and blow pipes in the laboratory are at the extreme right of picture.

Interior view of petroleum products testing laboratory trailer looking forward.





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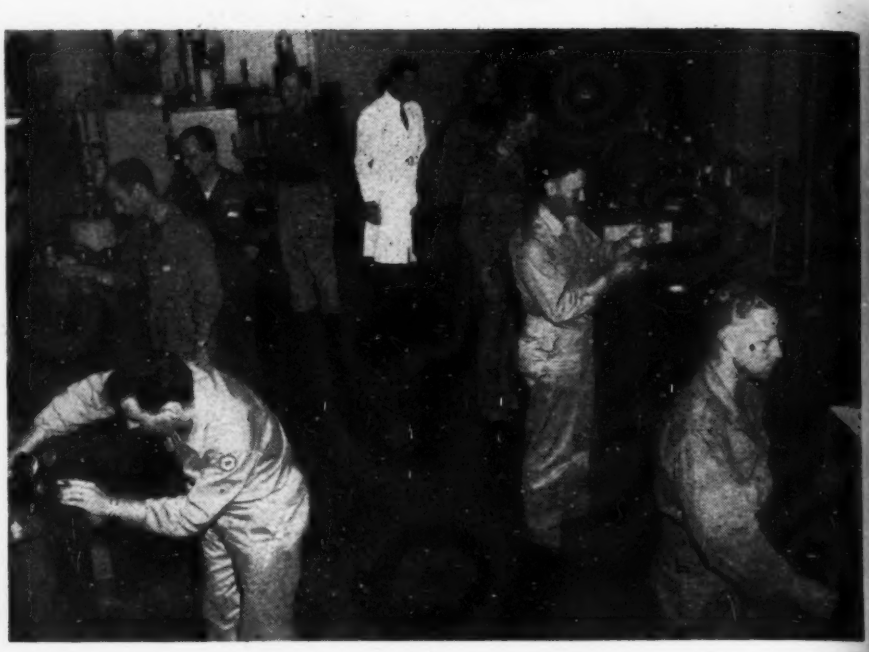

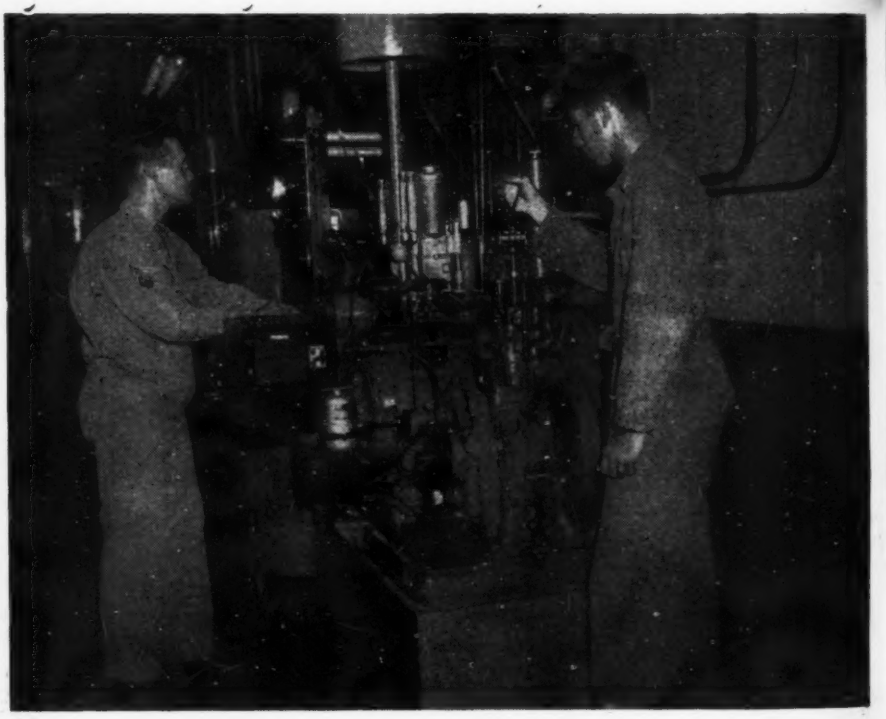

Quartermaster Petroleum School, University of Tulsa, Tulsa, Oklahoma. Above—C.F.R. knock testing instruction by Ethyl Corporation. Below—Light oil testing.

10 per cent, are trained for a period of 6 weeks in the operation of anti-knock engines at the Ethyl Corporation laboratories at Tulsa. This work is subcontracted to the Ethyl Corporation by the University of Tulsa.

An effort has been made by the army and air corps to send experienced and intelligent men to the university for training. Some of the men have had as much as 15 years' experience in the petroleum refining industry. There are more sergeants and corporals than privates and about 15 per cent of the students are commissioned officers, including the commanding officers of the respective units. The several sources of students are: (1) Quartermaster Corps from Camp Lee, Virginia, (2) engineer pipe line units from Camp Claiborne, and (3) the Air Transport Command.

The army maintains a supervisory officer at the school at all times. The officer in charge during the formulation of the course was Maj. Fred P. Robinson, who later was replaced by Lt. J. S. Clarke. The supervisory officer at the present time is Lt. R. H. McGuiney. All are from the Quartermaster Corps.

The classwork is conducted by Director W. L. Nelson, head of the department of petroleum refining; P. C. Blackburn, director of laboratory; D. A. Birkes, laboratory instructor; E. C. Davis, laboratory instructor, and Lt. A. L. Brenneman, who was loaned to the school by the army because of difficulty in obtaining qualified help. ★ ★ ★

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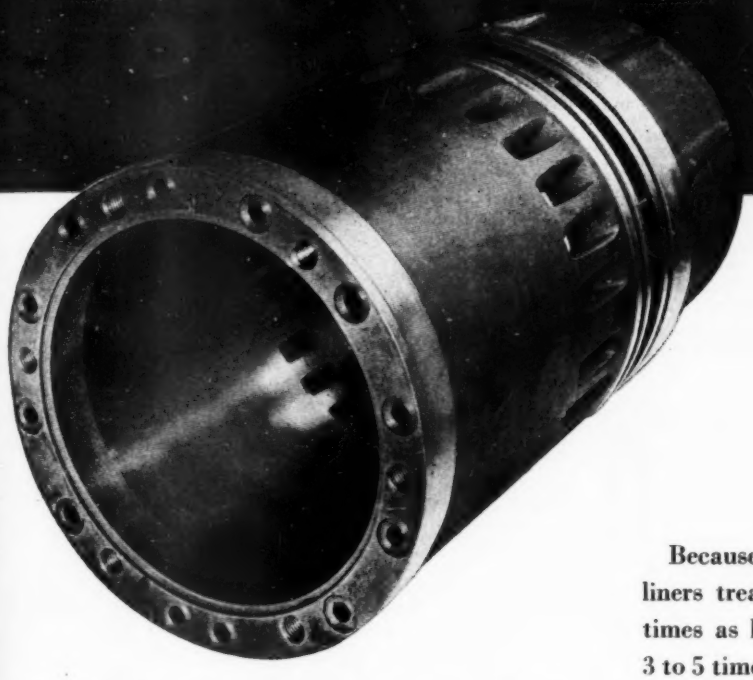

* PORUS-KROME is pure chromium, applied by the Van der Horst process that produces pores to hold oil. It reduces wear and corrosion and greatly multiplies cylinder life. It is being applied to engine parts in the three Van der Horst plants, and by license agreement.

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U. S. OIL INDUSTRY GROWS UP

By ERNESTINE ADAMS

Petroleum has rags-to-riches history in 85 years; shunned in 1859, it is now sought everywhere

EXCLUSIVE It is almost an understatement to apply the adjective "colossal" to the petroleum industry on this eighty-fifth anniversary. No one man can comprehend the size and range and influence of the oil industry after a mere fourscore and five years as a business.

Although known before the beginning of history, petroleum lay hidden and virtually useless until the people of a new and lusty nation, still intoxicated by political independence and private business enterprise, founded what might be termed the greatest industry in the world.

Incredible as it now seems, only 85 years ago petroleum was avoided and even dreaded by farmers who did not want the smelly stuff in their water wells or in the streams where their livestock sought water. Today it is the highest desire of many nations. The Axis countries bow before the stocks of oil in the hands of the Allies. Economic progress seems to be measured by the quantity of petroleum a country has. This tremendous influence has come about in an instant of time as history goes.

The staggering contrasts shown by the statistics in the table allows a limited understanding of the stout healthy industry that, big as it is, may very well be just on the threshold of its greatest advances.

The intangibles are even more impressive. Imagine the Machine Age in 1859 compared to what it is today. In the early part of the 18th century the new machines were lubricated by animal and vegetable oils and some "coal oil." The petroleum industry propelled the machine movement to its present volume. It is difficult to conceive of that rapid development without petroleum.

Who can measure the influence of the oil industry upon the economic progress of America. More than any one thing, petroleum has made the United States the leading nation of the world today.

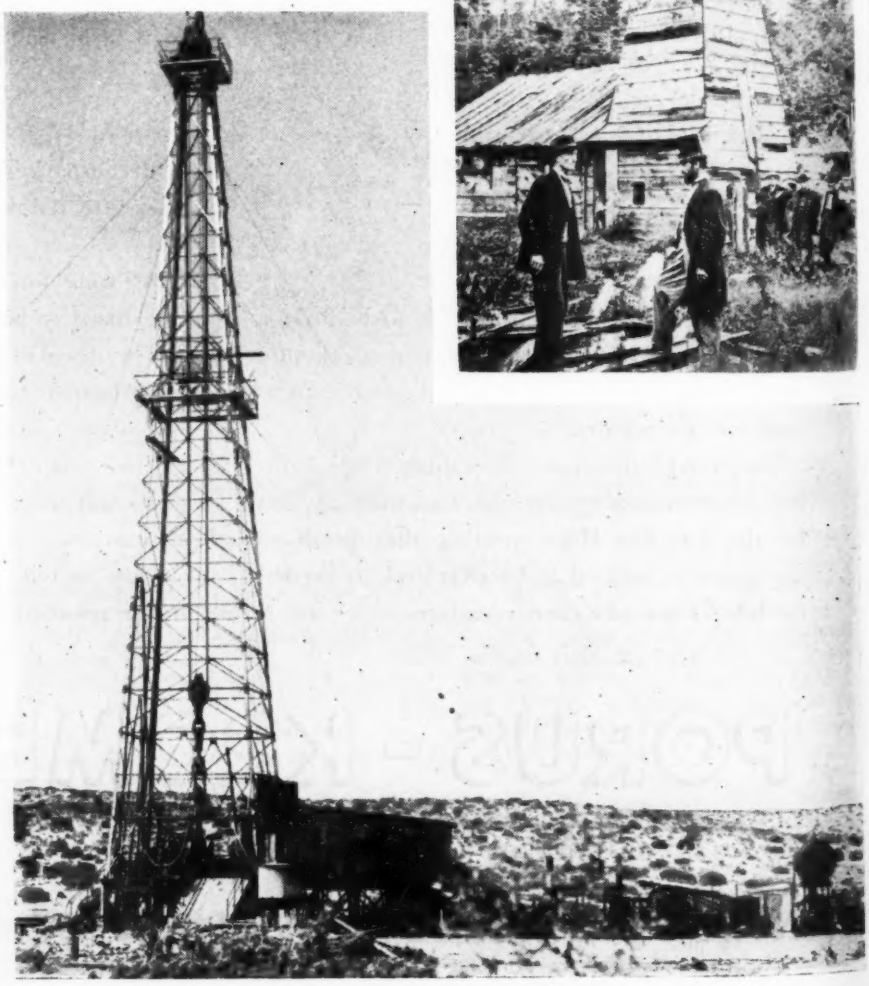
They didn't know it then but lights began going on all over the world when "Uncle" Billy Smith walked over to see the Drake well on August 28, 1859, and found the 69½-foot hole full of oil.* The event was but a feeble reflection of the power it released.

"Colonel" Edwin L. Drake, famed discoverer of the Titusville well, resembled the general conception of the average American taxpayer—quiet, stubborn, honest, often broke, and forever hopeful. He persistently held to his purpose of finding underground oil when his scheme was considered the utmost folly, even by some of the men who gave him financial backing. The fact that he was supported until he had successfully accomplished his aim is evidence of the personality of the man. Even though his idea was ridiculed, he obtained money to go ahead, first from the Seneca Oil Company and later from Titusville friends.

The discovery was greeted by virtual silence on the part of the press, surprise but small real interest by the neighborhood, and by quick and sudden action on the part of an embryo oil industry. Although they had to make up methods as they went along, the early operators were soon leasing, gambling, digging, drilling, completing, producing, shipping, and marketing.

The hopeful seekers of black gold didn't know how to find oil but they had the only clue they needed—that there was oil to be found. They didn't know that gas could make a well flow but they learned that in the explosion of 1861 when a "fountain" well came in and the gas was accidentally fired. They didn't know that a well could be flooded by

A glimpse of changes brought in 85 years of the oil industry is seen in the contrast between the squat wooden derrick of the Drake well and the shaft of steel at the site of the Phillips No. 1 Price, the world's deepest well. Colonel Drake is standing before his well with a friend, Peter Wilson, at left.



*The Birth of the Oil Industry, Paul H. Giddens. The Macmillan Company, 1938.

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water but they learned that at Pithole. They thought that oil followed the streams but they learned at Cherry Run that it could also be found under the hills.

They didn't know anything about petroleum geology but every well was a lesson. They had no oil maps to study but they soon made maps of all the known fields. There weren't enough wash tubs to store the first oil so some one thought of barrels and when barrels weren't enough they dreamed up the iron tank.

It was an independent tough industry from the first. When teamsters got too rambunctious some one figured out the use of pipe lines to transport oil. When the railroads threatened a monopoly on carrying oil the operators learned that oil could be pumped through a pipe line over a hill. When the $1 a barrel tax of the federal government threatened to shut down small wells all over the oil region, the oil men began their first effective association for cooperative action and obtained a repeal of the tax in May, 1866.

A collection of materials used by the budding oil industry is found in the Drake Museum, a neat brick building in the Drake Well Memorial Park. The American Petroleum Institute established the park with a museum and library in 1934. Paul H. Giddens, curator of the park and author of the book, "The Birth of the Oil Industry," has added to the great historical collection of documents and oil well tools. Those who have items of historical interest to the industry or know any one who has are asked to communicate with Giddens, Drake Well Memorial Park, Titusville.

TABLE OF CONTRASTS

1859	1944
Uses	
There were three uses of petroleum: For a cure-all medicine chiefly, for a luminant that was smoky and unsatisfactory, and for a lubricant, that is if animal or vegetable oil was unavailable.	More than a thousand tested uses with new ones pressing against the laboratory door for instant release after the war. Recent advances have been widest in the field of petroleum chemistry.
Market	
Only the few people in the immediate vicinity of oil seepages made any use of petroleum except those who bought it by the bottle for medicine.	The market today means all civilized peoples and may by now include many savage tribes who live where war has crossed their paths.
Production	
Drake's well came in for about 20 bbl. a day on the pump. During the year some 200 bbl. were recovered. A.P.I. gives 508 bbl. for 1859 and 1860.	Estimated U. S. production for the year is 1,600,000 bbl. War limits information of foreign production but it may be roughly half that of U. S.
Depth	
Drake's well on Oil Creek, Venango County, Pennsylvania: 69½ ft.	Deepest well is Phillips No. 1 Price, Pecos County, Texas: 15,279 ft.
Price	
Price of oil, $20 bbl.	Price today, $1.35 bbl. average.
Refining	
Samuel Kier, pioneer oil refiner, had a small still but the common method was to heat the oil and strain it through a heavy cloth.	Hundreds of big plants are now built to handle the complicated and highly technical refining processes that have been developed.
Transportation	
Crude oil was pumped into wooden barrels, loaded on wagons, and hauled to the refinery. Later iron tanks were put on railroad flat cars. In 1865 the first pipe line was laid.	Thousands of miles of pipe lines, thousands of wooden, steel, and concrete tankers, and thousands of steel tank cars carry crude oil to the refineries and products to distributing points.
Investors	
Investors in 1859 were some score of men who organized Pennsylvania Rock Oil Company and eventually changed it to the Seneca Oil Company. It was capitalized at $300,000 but only a few thousands changed hands.	In the United States there are some 1,500,000 persons who have invested in the oil business; probably more people than in any other industry in the world. Total investment is estimated at about $17,000,000,000.*
Organizations	
No organization of oil operators existed at first but in 1866 they acted collectively to repeal a heavy tax and in 1869 organized the Petroleum Producers Association.	Every phase of the industry is represented by some strong cooperative organization to share information and advance the aims of the industry and of its several branches.
Literature	
No written record guided Drake. Although known before history there was the most meager information on petroleum. Drake hired a blacksmith and a string of tools for sinking brine wells to drill the first well, and succeeded by trial and error.	Libraries covering the data of experiment and experience for every step in the process of seeking, developing, and marketing petroleum are available to every operator. A rich accumulation of literature provides a guide for those of today.

**Petroleum—1944*, Merrill Lynch, Pierce, Fenner and Beane.

The refiners, following the pioneering of Samuel Kier, had prepared oil for lubricants and luminants and they began experimenting with methods of refining petroleum for fuel for engines. The producers organized the Petroleum Producers' Association in 1869 at Titusville to deal with overproduction and price structure. The idea of integration of the oil business was already revealing advantages. The producer who could transport his oil, refine it, and market it, could not be so easily squeezed out of business.

Thus, the skeleton structure of the industry was shaping up 10 years after Drake completed his well. Fundamentally it has changed little although the squat wooden derrick has given way to the obelisk of shining steel. The willow twig has been replaced by the science of the geologist and geophysicist. The effort of the Titusville association to control production was only a forerunner of the great Compact of oil states.

Collective action has strengthened with each fresh realization of its need. Although the collective efforts of the industry for fair prices today have not met with the success of the 1866 delegation that won repeal of an unfair tax, in many other directions cooperation has made great gains. Drilling and production, proration, secondary recovery, and water disposal, geological surveys and transportation—these and all other operations of the industry have felt the stimulus of collective effort in their development.

Eighty-five years ago this month one well had been drilled for oil. The industry today is working toward its two-millionth well with about 80 per cent of them at some time producers of oil or gas or both. To the vigorous spirit of private enterprise and its twin paradoxical attendants, competition and cooperation, goes the credit for the phenominal growth of the giant petroleum industry. ★★★

Rough on rope!

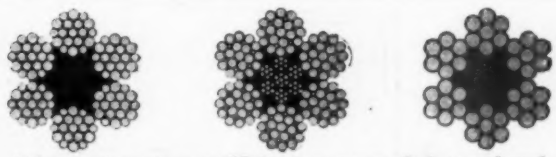
War lives on it, and civilians walk . . . while a hungry world probes for oil as never before. Last year within the United States, almost twenty thousand wells were started. And with many a driller, Rochester Ropes are a "must" specification.

No industry makes any more gruelling demands on wire rope. The steady strain of dead weight, the pull of the casing, the fishing for lost drills or twisted casing . . . the mud, sand, gravel, brine, damp, heat and cold at various levels . . . require rope built for tough going, stamina in every strand! And in the oil fields, as well as in the contractors' camps, steel mills, shipyards, mines, skyscrapers, plane plants, shipping . . . wherever the specifications are severe and requirements rigid, you'll find Rochester Ropes doing hard jobs well, safely, cheaply.

All our present output is restricted to government and high priority industries. But for the best in wire rope tomorrow, remember the name—Rochester!

Culpeper Va. and Jamaica, N. Y. plants

ROCHESTER *Ropes*

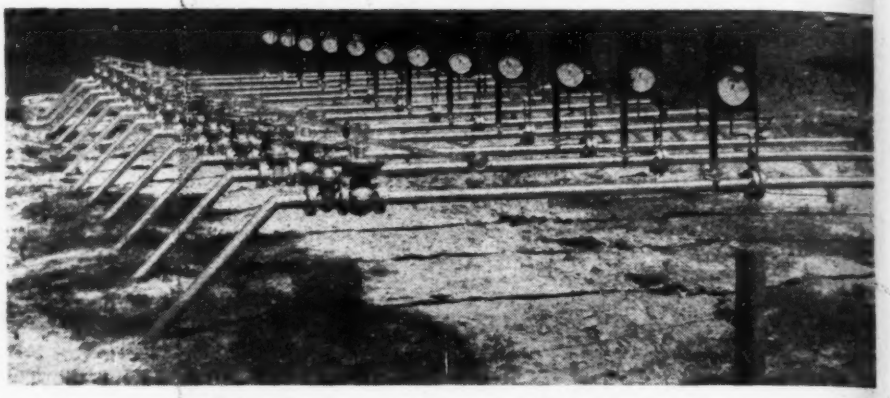


Wire rope is precious now! Take proper care of what you have!

HAWKINS PLANT MANUFACTURES FIVE PRODUCTS

By R. L. LANE*

Absorption-type unit supplied by 480 wells



Orifice meters and regulators are grouped in one corner of the plant grounds.

EXCLUSIVE There has recently been completed, by the Natural Gasoline Corporation and Humble Oil and Refining Company, a gasoline plant in the Hawkins pool, Wood County, Texas. This plant, utilizing all available material from two plants, which were dismantled, was designed to process 15,000,000 cu. ft. of gas per day, with atmospheric pressure at the field separators and 6 in. vacuum at the plant.

The gas is compressed to 200 lb. gauge in 2 stages with five 600-hp., angle type, compressor engines. The gas is intercooled and aftercooled through atmospheric coil sections in a cooling tower. The first stage condensate is pumped in with the rich oil going to the still and the second stage condensate is pumped directly from the second stage accumulator to the de-ethanizer and the non-condensable gas is then carried through a conventional type absorber operating at about 200 lb. gauge pressure. The rich oil is then fed to a vent tank where the pressure is reduced to 125 lb. pressure. Vent gases from this tank are returned to the second stage compressor suction. The rich oil is heated through oil-to-oil exchangers and a steam preheater. It is then fed to a combination still and dephlegmator.

The still is operated at 70 lb. gauge with a top temperature in the neighborhood of 220°F. and a bottom temperature of 370°F. The stripping steam is superheated with live steam before entering the still.

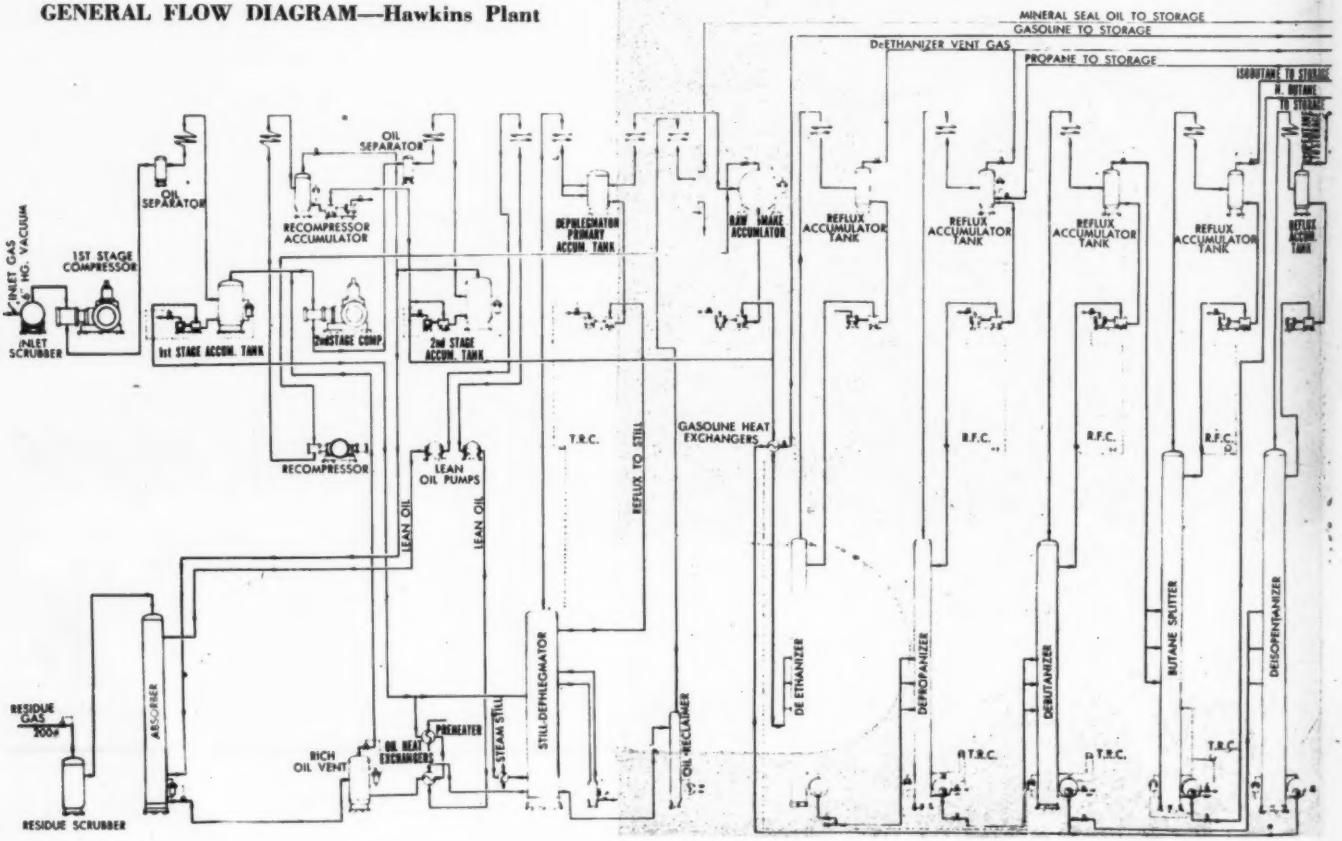
The stripped oil passes through the oil exchangers and is then pumped through open-type coil sections and fed back to the absorber. A side stream of oil is taken from the base of the still where it is reclaimed and returned to lean oil storage. The volume of oil reclaimed only amounts to 1.5 gal. per min., but is enough to maintain the quality of the entire oil stream.

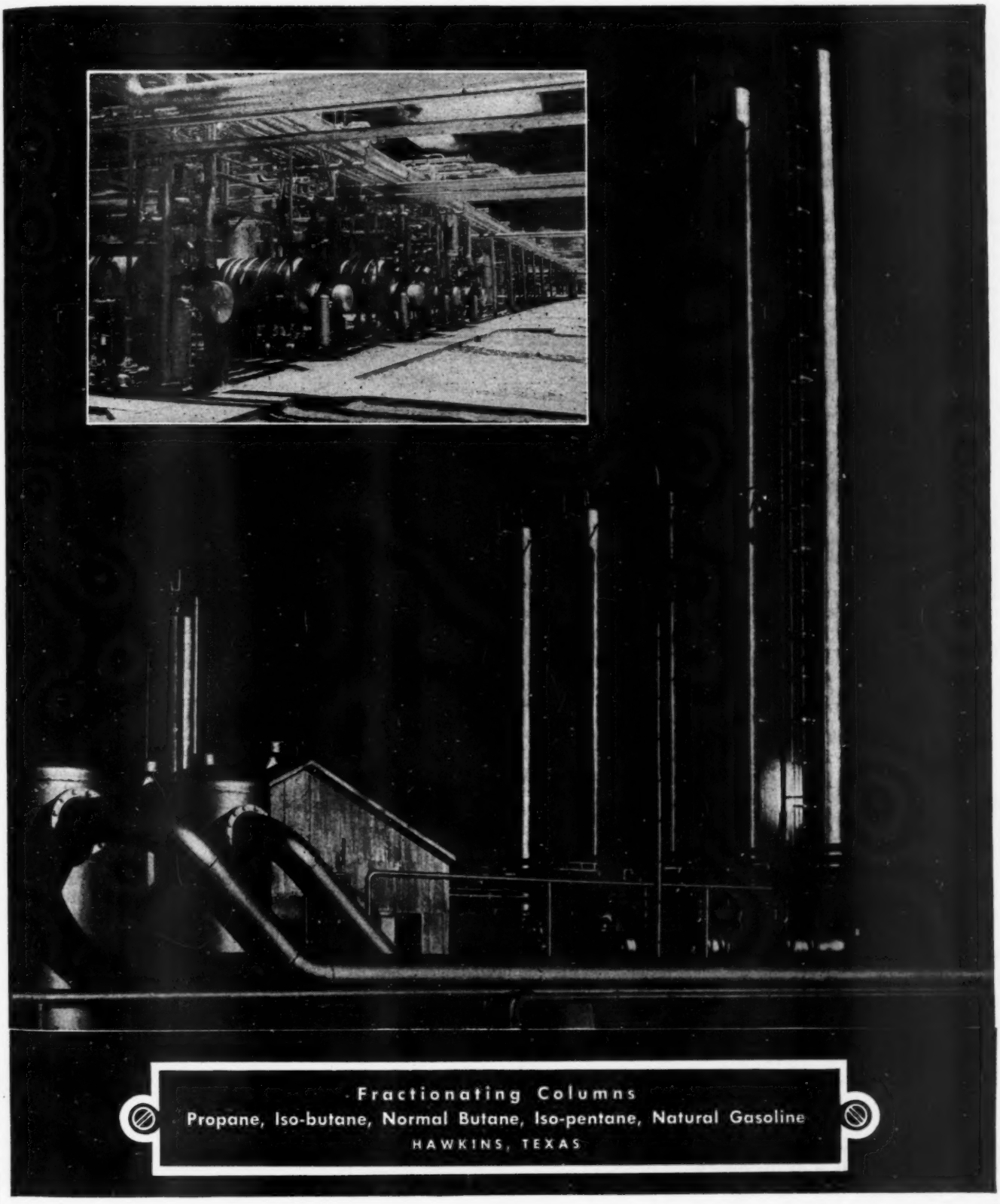
Still vapors are cooled in two stages by atmospheric coils—the first stage condenses only enough to provide reflux to the dephlegmator section while the second stage, or final cooler, condenses the major portion of the vapors. The non-condensed vapors are recompressed to 230 lb. gauge and cooled and the condensate is pumped directly to feed to the de-ethanizer and the non-condensing vapors are returned to the absorber gas feed.

The composite raw gasolines are then pumped to a 30-tray de-ethanizer operating at 450 lb. gauge. The ethane and lighter are fractionated out of the gasolines and taken overhead where enough of the ethane is condensed to maintain reflux to the column. All excess gases are vented to residue. Column temperatures are approximately 220°F. base and 110°F. top.

*Processing engineer, Natural Gasoline Corporation.

GENERAL FLOW DIAGRAM—Hawkins Plant





Engineered-Designed-Constructed

by

GASOLINE PLANT CONSTRUCTION CORPORATION

713 SECOND NATIONAL BANK BUILDING

HOUSTON, TEXAS

Gasoline from the reboiler on the de-ethanizer is then fed directly to a 34-tray depropanizer, which operates at 250 lb. gauge, with a top temperature of 128°F. and a base of 226°F. The propane is taken overhead and condensed with reflux being taken from the accumulator and the propane run to storage. Gasoline from the reboiler is fed to a debutanizer column.

The debutanizer is a 34-tray column and operates at 130 lb. gauge with temperatures of 160°F. top and 250°F. bottom. Isobutane and normal butane are taken overhead and totally condensed through open coil sections. These products are fed to a butane splitter. The base products, pentanes and heavier, are fed to a deisopentanizer.

The 64-tray butane splitter operates at 110 lb. gauge with temperatures of 130°F. top and 160°F. base. Isobutane is carried overhead, condensed, and sent to storage. The reboiler product, consisting of normal butane, is cooled and pressures to storage.

The deisopentanizer column, of 64 trays, operates at 55 lb. gauge with a base of 205°F. and a top of 172°F. Isopentane is taken from the top of the column through condensers to storage. Bottoms from the reboiler, an 8.5 to 9.0 R.v.p. gasoline, are transmitted through coolers to storage also.

An average daily production will approximately show:

Propane	**14,500 gal.**
Butane	**14,000 gal.**
Isobutane	**12,000 gal.**
Isopentane	**6,000 gal.**
8.9-lb. R.v.p. gasoline	**15,500 gal.**
Total	**62,000 gal.**

A typical analysis of inlet gas is as follows:

Component	*Mol. %*	*G.p.m.*
CH_4	72.27	
C_2H_6	9.76	
C_3H_8	8.44	2.31
iC_4H_{10}	3.13	1.02
nC_4H_{10}	2.58	.81
iC_5H_{12}	1.12	.41
$nC_5H_{12}+$	2.70	1.04
Total	**100.00**	**5.59**

Residue gas analysis:

Component	*Mol. %*	*G.p.m.*
CH_4	85.70	
C_2H_6	10.41	
C_3H_8	3.68	1.01
iC_4H_{10}	.21	.06
Total	**100.00**	**1.07**

One cooling tower is used for the entire plant cooling. It is of the conventional louver type, with a coil shed below the V-pan. This tower is 26 ft. wide by 210 ft. long and has a dual water system, one of which puts water over the tower and the other takes water from the basin and puts it directly over the jacket water and oil cooler coils. Water from the cooling tower V-pan is distributed over the other coils in the tower. It might be noted, at this point, that all cooling and condensing is done in open coils in this tower.

The steam power plant comprises seven 125-hp. oil field boilers with superheaters. Boiler feedwater is handled in a 3-stage operation. One low pressure tank receives condensate and low pressure steam, after which it is deaerated and pumped into a high pressure tank along with any necessary makeup water. The second stage condensate tank operates at 10 lb. pressure and the so-called high pressure tank operates at 45 lb. pressure. Some exhaust steam and condensate is fed direct to this tank from the manufacturing area.

Fractionators, cooling tower, transfer pump house, and compressor section.

Electricity is supplied to the plant by three 100-kw. alternating current generators direct-connected to 150-hp. engines. Water is supplied to the plant by two wells located on the plant site and is pumped by motor-driven deep well type pumps. Storage for all products has been provided for at the plant site. The capacity of this storage is about 600,000 gal.

To handle loading of products, a transport dock, adjacent to the office at the plant site, is equipped to load any of the 5 products manufactured as is also the railroad loading rack, which is about one mile east of the town of Hawkins. A camp was constructed immediately south of the plant for the employees, which is modern in all respects.

There are about 480 wells in the Hawkins field from which gas is taken. All gas is received from separators that carry pressures from 0 to 15 lb. gauge. The operators in the field are elevating all separators, which will enable gas to be delivered to the gathering system at about atmospheric pressure. This will materially increase production at the plant.

There are about 250 meters in this field due to the large number of Hawkins townsite leases and different royalty owners. In the townsite area, these settings have been grouped with as many as 16 settings at one place thereby expediting the work of gathering charts and repairing meters. Most of the wells in the field flow their daily production in from 6 to 12 hr. and require careful scheduling to maintain a constant flow into the plant. The gathering lines were sized and laid out with this in mind.

There are about 110 miles of pipe line in the field ranging in size from 24 in. to 2 in. in diameter. This includes the gathering, residue, and loading systems.

The gasoline plant was designed and constructed by the Gasoline Plant Construction Corporation of Houston, Texas. Construction was under the supervision of W. R. Walker of that company. The field system was designed and surveyed by company engineers, while the pipe lines were laid by Anderson Brothers Construction Company of Tulsa, Oklahoma.

All products manufactured at this plant are handled and sold by the Warren Petroleum Corporation, Tulsa, Oklahoma.

The superintendent, Guy Barritt, was in charge of the Natural Gasoline Corporation's interests during construction and is now operating superintendent. Emmett Hodge is assistant superintendent in charge of the field activities.

★ ★ ★

Frontiers grow, too

"Our frontiers are greater today than ever before. Why, since 1932 the oil industry has produced more oil than was produced in all the years before 1932. Many other industries have made similar records. Many new industries have since been born.

"There are today hundreds of new enterprises using catalysts (similar to our Houdry Process), electronics, plastics, and other chemicals that were not in existence in 1932. And hundreds more await only the individuals who are willing to take the chance to bring them into existence."

—J. Howard Pew, president
Sun Oil Company

...at LESS Cost!

The new FLUOR Counter-Flow Induced Draft Cooling Tower makes obsolete all previous standards for cooling tower performance per dollar of cost. Here are just a few reasons why:

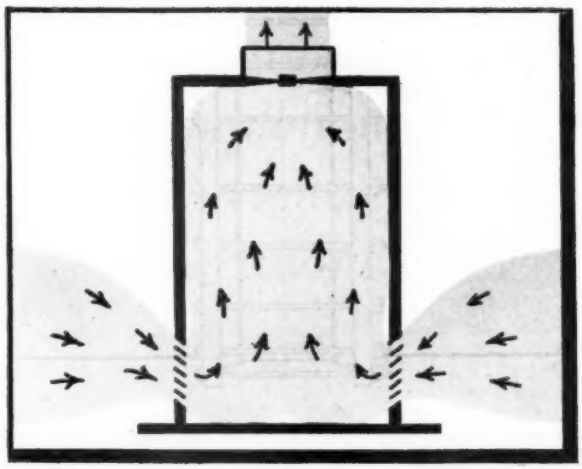
It more nearly approaches the optimum efficiency of true counter-flow heat transfer. Air and water, flowing in opposite directions, are brought together in longer and more thorough contact.

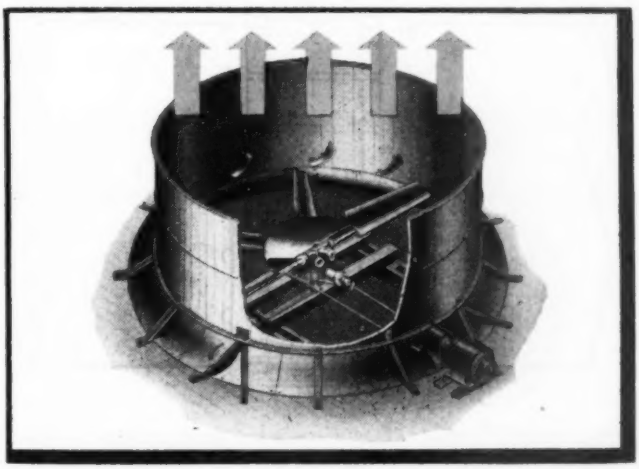
Greater distance between the point of high velocity saturated air discharge on top of the tower and the fresh air intake at the bottom of the tower minimizes recycling often found in ordinary mechanical draft cooling towers.

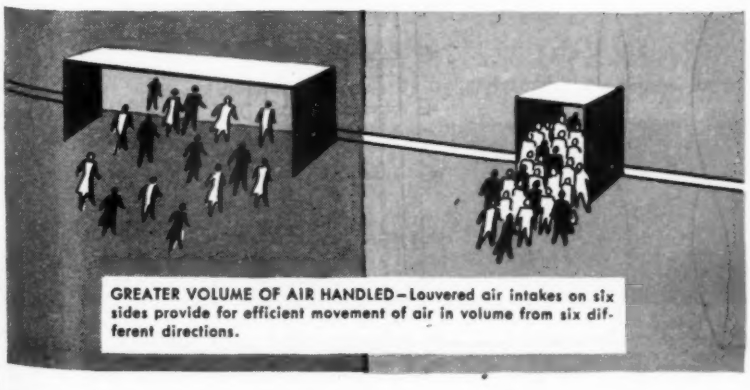
Greater heat transfer per unit of ground space reduces the number of fans and power-consuming mechanical equipment required since each cell does 40% more cooling than an identical tower 25 feet high. To saving in ground space is also added substantial reduction in the amount of concrete, reinforcing steel and other materials used in cooling tower basins.

These advantages, plus Fluor Shear-Plate Construction, complete pre-fabrication, Aerator panel exterior, and many other Fluor "firsts" make the new Fluor Counter-Flow Induced Draft Cooling Tower an important advancement in cooling tower design and performance.

All designs for FLUOR Aerator Cooling Towers and FLUOR Counter-Flow Induced Draft Cooling Towers are fully protected by U. S. Patents and Patents Pending.







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COUPLING BONDING ON NATURAL GAS PIPE LINES*

By F. J. McELHATTON†

Making of line into a continuous structure is essential for application of cathodic protection

IN HIS FIGHT against corrosion, the engineer in the natural gas industry has one problem to overcome that engineers in other industries do not encounter. This additional problem is present because the major portion of the natural gas lines are constructed with mechanical couplings having rubber gaskets. These couplings occur every 20 to 40 ft. in most natural gas lines. In the application of cathodic protection it is necessary that they be electrically bonded to make the pipe line a continuous structure providing a low resistance metallic path in the pipe for the d-c. current return.

▼ **Bond requirements.** In selecting and installing bonds or shunts, the following should be given consideration:

1. The bond should be of extremely low resistance, the ideal bond being one of a resistance that will approach that of the pipe itself. As the pipe sizes used offer a path of extremely low resistance, however, this is not practical. Therefore, the largest bond that can be used economically should be applied.

2. The bond should be applied to the pipe line in such a manner that it will not fail and will remain in good condition throughout the life of the pipe line.

3. The cost of the bond should not be excessive. Cost is, of course, determined by the size of the bond and the method of manufacture.

▼ **Types of bonds.** There are numerous types of bonds that can be made, but this paper will deal only with five methods of bonding that have been used and tested on our system.

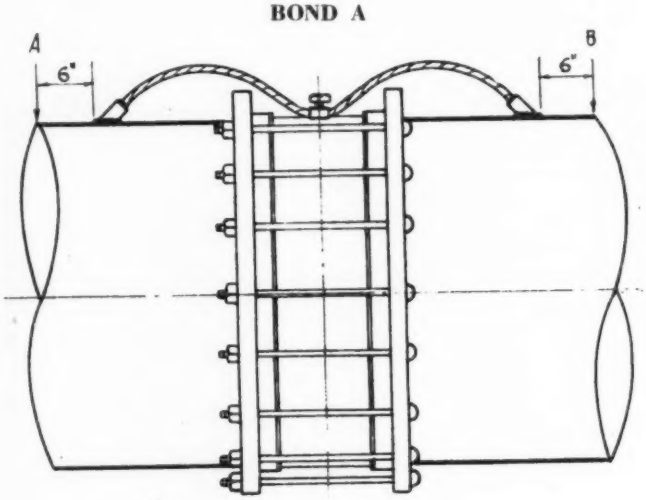
Bond A is made of 4/0 19-strand copper on the ends of which have been brazed ½-in. pipe nipples 2 in. long. The object of the pipe nipples, which are installed in central shops, is to permit a steel-to-steel weld in the field. The center of this bond is clamped to one of the bolts in the coupling by the use of a cable clamp. In this manner the mechanical coupling itself is included in the circuit.

Bond B was used in 1/0, 2/0, 3/0, and 4/0 solid copper, bent so that it was possible to tack weld the copper to the center ring and both followers of the coupling, including it in the circuit. When welding this bond of copper direct to the steel pipe, a very strong, satisfactory bond was obtained by using ferroweld rod and reversing the polarity of the arc

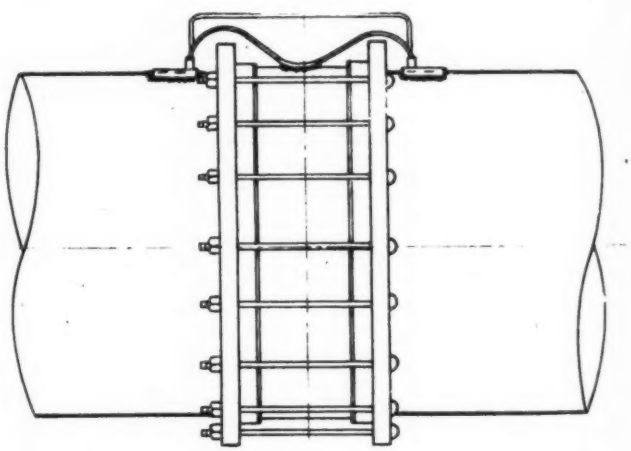
*Presented before National Association of Corrosion Engineers, Houston, Texas, April, 1944.

†Panhandle Eastern Pipe Line Company, Kansas City, Missouri.

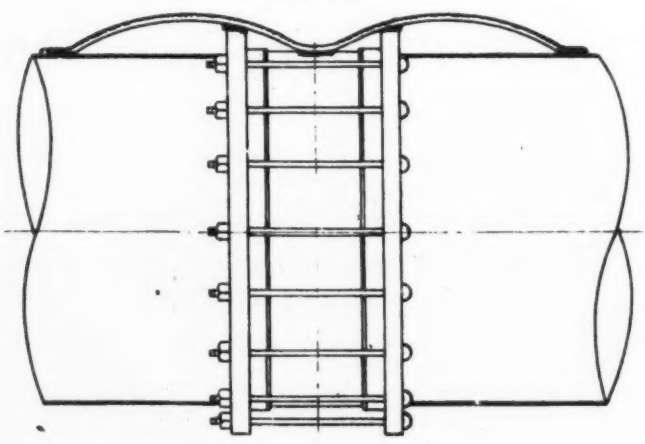
BOND A



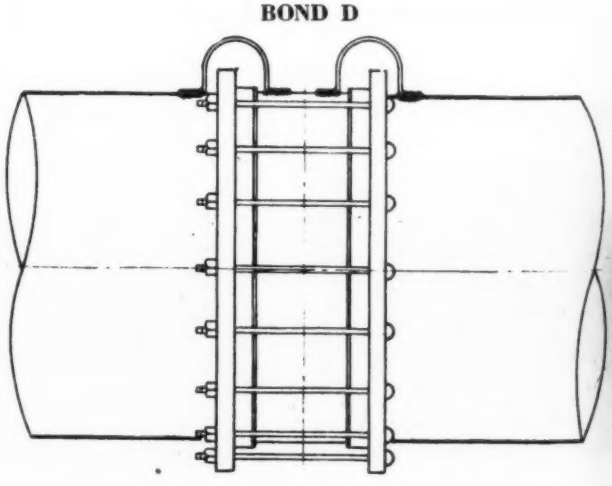
BOND C



BOND B



BOND D

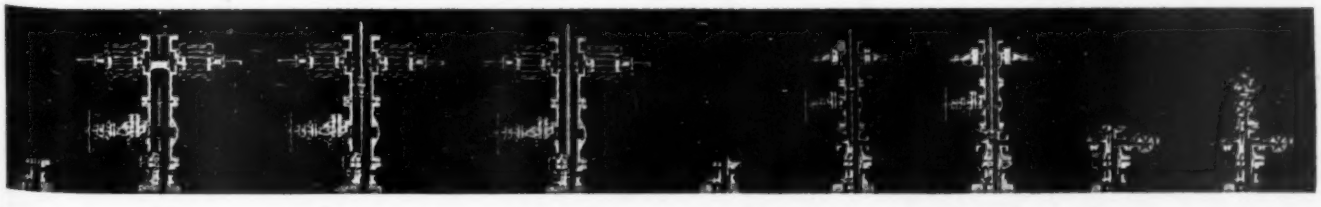


THE WHOLE IS GREATER THAN ANY OF ITS PARTS

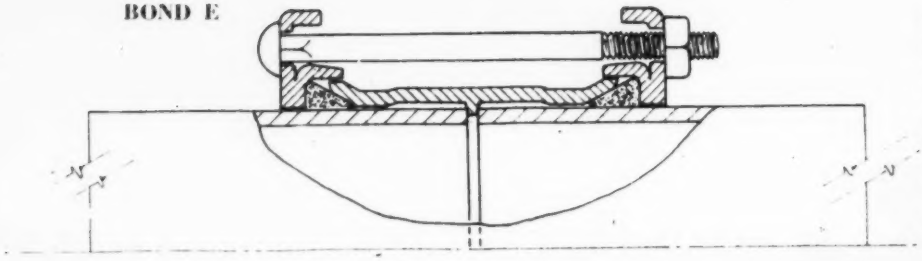
EVERY STEP *performed in the completion of a well has a lasting governing effect on the steps of completion which must necessarily follow. If the equipment initially installed is such that additional operations beyond the progressive steps are required, in order to give the equipment that which it lacked when operations were commenced, the effects of these additional operations on necessary succeeding steps in the completion of the well cannot be avoided. Their injurious effect will be multiplied in succeeding operations.*

GRAY
TOOL COMPANY
HOUSTON

West Coast Distributor: WAGNER-MOREHOUSE, INC., Los Angeles. *Export Representative:* GUY E. DANIELS, 30 Rockefeller Plaza, New York City



Casing Head Attached | Drilling | Running Casing | Casing Landed | Drilling Control Equipment Removed | Drilling-in and Running Tubing | Tubing Landed | Control Equipment Removed | Manifold Attached



welding machine. One disadvantage with this type of bond was the fact that toxic gases passed off during the welding, necessitating the use of an exhaust fan to prevent injury to the welder.

Bond C is available in different capacities. It consists of a flat, solid copper strip with 2½-in. by 1½-in. by ¼-in. steel terminal plates that are curved to fit the curvature of the pipe. The steel-copper joint is a factory weld giving a uniformly good joint electrically as well as mechanically. A 3/16-in. galvanized steel wire is welded in parallel to the copper strip. This steel wire can be bent and welded to the followers and center ring of the coupling, including it in the circuit.

Bond D consists of a steel strap, 3 in. wide by 3/16 in. thick, bent in the shape shown to permit placing it over the followers, welding one end to the pipe and the other end to the center ring. Two bonds of this type are required for each coupling. It was interesting to note that the second pair of this type of bond installed on a coupling by no means lowered the resistance by one-half. Seemingly the first complete bond from pipe to center ring to pipe had by far the most effect. One disadvantage of this type of bond is the difficulty encountered when it is necessary to remove a joint of pipe. This is especially true in areas where, due to escaping gas, it is not possible to use a cutting torch and a cold cut or hack saw must be used.

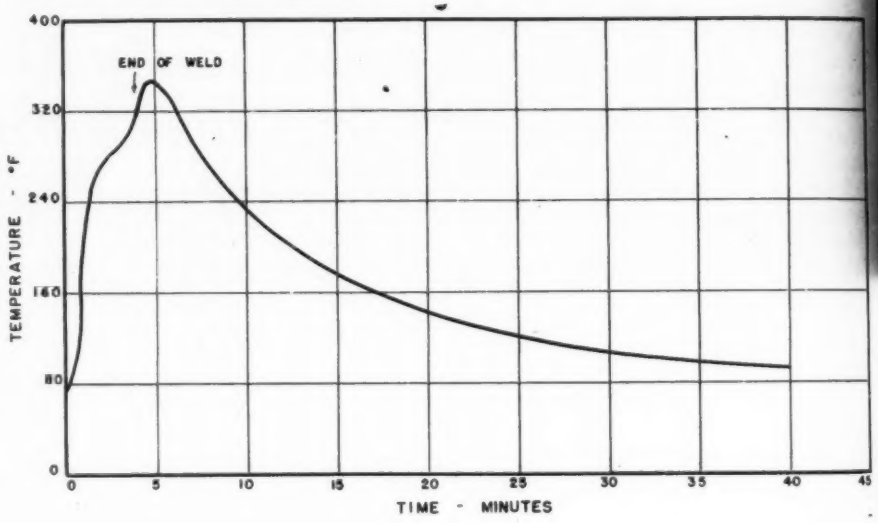
Bond E, known as an armored gasket, is comprised of a standard gasket with a continuous-ring close-coiled helix of brass wire molded in the extreme tip; that is, the portion adjacent to the clearance between the center ring of the coupling and the pipe. The armor is as flexible as the gasket itself, permitting the armor to conform to variations in the pipe or any irregularities of the surfaces. When the coupling followers are drawn up, the gasket forces the armor against the center ring and the pipe, making the joint electrically continuous. This type of joint can be used satisfactorily when used during the construction of the pipe line but it would be impractical to install it on existing lines due to the installation cost.

▼ **Methods of applying bonds.** In bonding the couplings on our system, many methods of joining the copper to steel have been tried with varying degrees of success. These methods consisted of mechanical connections, soldering, brazing, oxyacetylene, and electrical arc welding. Of these methods, we have found the electrical arc welding to be the most reliable and satisfactory. This proved to be true in all cases whether it was a copper-to-steel or a steel-to-steel weld.

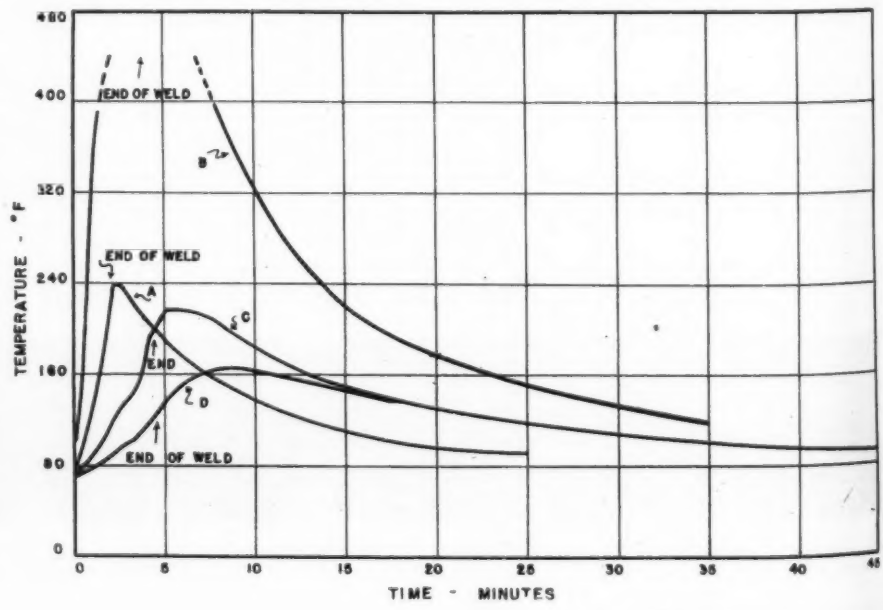
When oxyacetylene or flame welding was used, consideration was given to the possibility of damaging the coupling gaskets and a longer bond was used, placing the weld 5 in. away from the coupling. As only a small amount of this type of welding was used in bonding, no tests on temperature rise were conducted by our organization. The attached curves, Fig. 1 and Fig. 2, showing the heat occasioned on the pipe at the coupling follower, were prepared by the American Steel and Wire Company from results obtained from laboratory tests. They are reproduced here with company permission.

▼ **Resistance tests.** The following table shows the results obtained in overall ohmic resistance between points "A" and "B", each point being 6 in. from the

Welding test on pipe coupling shunt. Flamewelded terminal 1 in. from coupling flange. Flange protected from direct welding heat by wet asbestos pack. Oxweld No. 30 tip. Temperature measured on pipe at coupling flange adjacent to terminal being welded.



Welding tests on pipe coupling shunts. A—Arcweld-term. 1 in. from coupling flange; B—Flameweld-term. 1⅜ in. from coupling flange; C—Flameweld-term. 3 in. from coupling flange; D—Flameweld-term. 5 in. from coupling flange. Temperature measured on pipe at coupling flange adjacent to terminal being welded. Curves A and B taken with flange exposed to welding heat. Curves C and D taken with flange protected from direct welding heat. ⅛-in. steel electrode Oxweld No. 30 tip.



MISSION SLUSH PUMP VALVES

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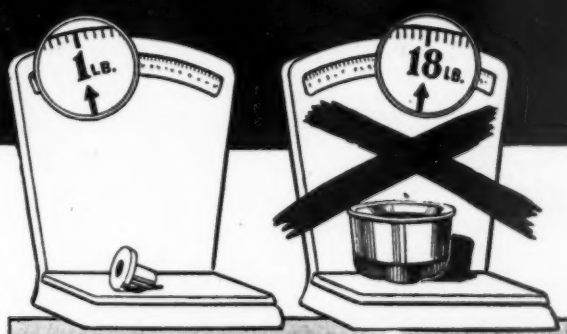
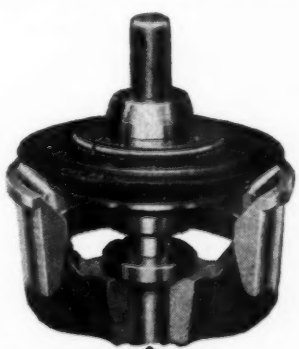


YOU SAVE STEEL BY CHANGING A 1-POUND BUSHING INSTEAD OF AN 18-POUND SEAT

In the Mission Valve, this small bushing takes the wear instead of the larger, more expensive valve seat. You save both money and metal with the wear-taking bushing.

This bushing saves metals needed for defense — and keeps your pumps running more economically because it takes the wear normally taken by the heavy valve seat. It is durable and economical . . . By changing it at the right times you can make the seat last much longer than ordinary seats . . . . saving metals and reducing valve seat replacement costs.

CHANGE THE BUSHING AND SAVE THE SEAT



But remember, that's only one of the features of Mission Slush Pump Valves. For example, Compound-308 Valve Inserts are establishing new endurance records every day.

So consistent has been the superiority of these valves that *we guarantee them to be the most economical valves on the market to operate.* Order a set for your pumps today.

Use all
MISSION PUMP PARTS
They work together for best all round performance

4A-11

Mission MANUFACTURING CO.
HUMBLE ROAD HOUSTON, TEXAS

weld as shown on the diagram of Bond A. All tests were conducted on 24-in. O.D. seamless pipe. The measurements were taken with a wheatstone bridge.

	Length of copper in the bond, in.	Bond size	Microhms resistance
Bond A	18	4/0 copper	279.01
Bond B	18	1/0 copper	275.46
	18	2/0 copper	253.08
	18	3/0 copper	234.93
	18	4/0 copper	219.14
Bond C	18	1/0 copper	147.43
	18	2/0 copper	125.09
Bond D		3-in. x 3/16-in. steel	254.00
Bond E		Armored gasket	165.12

The test results shown from Bonds C and E do not agree with data obtained from the manufacturers of these two types of bonds. As we were unable to duplicate their results, it is assumed that their conditions were more nearly ideal.

It will be noted that the highest resistance obtained was with a bond 4/0 19-strand copper. (Bond A). It was impossible to obtain a low resistance joint when the ½-in. pipe nipples were brazed to the copper wire in the shops.

When testing Bond E, we assembled the coupling as it would be assembled in the field on construction. That is, the pertinent parts of the coupling were not cleaned more than if plain gaskets had been used. It was noted when the bolt pressure on the coupling was increased from 50 lb. per sq. in. to 85 lb. per sq. in. the resistance between the two points appreciably decreased.

▼ **Bell holing.** The principal cost in bonding of old pipe lines is the digging and backfilling of the necessary holes at the couplings to permit the installation of the bond.

Throughout our system the lines vary in depth from 30 to 84 in. with the major portion of the line having 36 in. of covering.

In the past, the necessary holes were dug by hand, resulting in rather high cost per hole. Recently we have found it is possible to dig holes 45 in. in diam. to 7 ft. deep with a power-driven helix auger. Under good conditions, it is possible to bore as many as 10 of these holes in an hour. An experienced operator is able to bore to within 2 in. of the coupling follower safely. This leaves very little hand digging. We are using this method at the present time with a reduction in cost per hole of approximately 50 per cent.

I would like to refer those engineers who have this problem of bonding to the resistances obtained in the tests. It will be noted that the lowest resistances were obtained with Bond C, a factory assembled bond. This type appears to be ideal for installation on existing pipe lines. It is interesting to know that we recently procured a large quantity of this type of bond at a very slight increase in cost over the types we have cut and assembled in our own warehouses in the past.

On new construction, where couplings are used, a good, satisfactory, economical bond of extremely low resistance can be obtained with the armored gasket if the necessary precautions are taken to see that all parts are clean. ★ ★ ★

Pumping With Compressed Air*

COMPRESSED air has been applied to actual lifting of water and other liquids from wells for better than half a century, but only in more recent years has engineering knowledge overcome the popular misconception regarding its utility and performance. The most universal application is, of course, in the pumping of water or oil from wells.

Consider an open well, or any body of water deep enough, regardless of its volume, or the nature of its enclosure—a pond, lake or river. In the water is suspended, or fixed, a vertical pipe for water and a pipe for compressed air. These pipes should be submerged for a certain depth proportionate to the lift when the pump is at work.

It is understandable that the water, being free to enter the lower end of the pipe, will rise to the same height inside the pipe as it stands outside the pipe. Now, if air is introduced under pressure through the air pipe into the base of the water pipe, the result is an air lift pump. The question at once arises regarding what will prevent the air from going down and thus discharging the water from the lower end of the water pipe rather than forcing the water up through the pipe.

The answer is this: The air operates as a pump to lift the water because the unbalanced hydrostatic pressure in the discharge pipe is from a mixed column of water and bubbles of air of less specific gravity than the water outside the pipe or below the air entrance. Thus the flow is started as this modified water seeks a higher level due to its lighter weight and the unmodified water is constantly being forced up by its own equalizing pressure into this lighter mixture. A continuous flow of compressed air into the discharge pipe creates a continuous pumping action. The amount of flow is dependent upon the amount and pressure of the compressed air introduced.

The principle of the air lift pump is illustrated in the accompanying sketch.

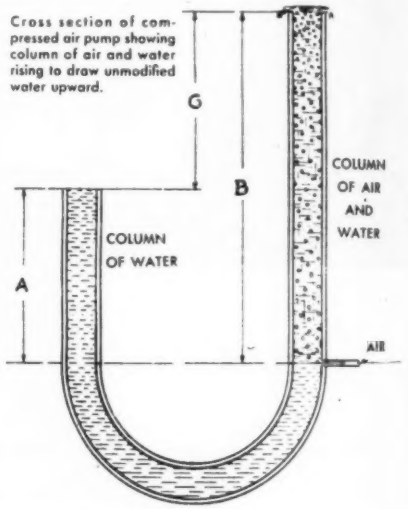
In using the air lift pump the following characteristic advantages will be apparent:

Large capacity. Limited only to the capacity of source of supply.

Simplicity and reliability. No moving parts of any description inside the well. All inspection on the ground surface for maintenance.

Low maintenance. An air compressor constitutes the entire equipment except in piping, and supplies the power through an air line into the well.

Flexibility. Compressor can be located at any convenient place where economical fuel is available. Compressed air may be piped from central compressor station to one or more wells.



Cross section of compressed air pump showing column of air and water rising to draw unmodified water upward.

Aeration. Water pumped with compressed air lift is improved due to constant aeration. This offers definite advantage for wells producing drinking water.

Other advantages include the air lift's ability to deliver from 40 per cent to 50 per cent more water during peak demands, and to handle gritty liquids and acids without damage to pumping efficiency.

The principle of pumping with compressed air rather than with mechanical devices, has logical applications in many fields. Contractors who have air compressors also have air pumps. They could use the principle here described for emptying water filled excavations or for filling supply reservoirs from adjacent streams and lakes. In the oil fields, the compressed air pump can be used to transfer impounded oil into storage, to repressure and pump out sluggish wells. An air lift pump can be rigged up quickly to bail out ships' holds or to fill tanks of ships operating in fresh water.

The uses of compressed air pumps are as limitless as the need for lifting liquids from one level to a higher level. The simplicity as well as the efficiency of the air lift pump lends itself to an ever increasing list of applications. ★ ★ ★

*Material by courtesy Compressed Air Institute.

Postpone meetings

Transportation difficulties have resulted in the cancellation recently of a number of oil meetings. The annual meeting of the American Petroleum Institute, scheduled for November 13 to 16 in Chicago has been postponed. The Texas Mid-Continent Oil and Gas association had previously cancelled its meeting, scheduled for October in Houston. Directors of the Independent Petroleum Association of America voted not to hold their annual gathering, which had been scheduled for Dallas during October. In addition to these meetings which annually attract hundreds of oil men from all sections of the country, a number of smaller gatherings of the oil fraternity also have been postponed.

Contamination by Successive Flow in Pipe Lines*

By FRANK. C. FOWLER and GEORGE GRANGER BROWN†

IN recent years a new problem in fluid flow has developed in the operation of product pipe lines. These pipe lines transport a number of different petroleum products through the same pipe line for distances of several hundred miles. These different products flow through the pipe line as successive slugs or "tenders" without any separating medium. Under these conditions mixing of the two streams always occurs to form a slug of contaminated material between the tenders of the different uncontaminated products. The extent and degree of mixing in this contaminated portion depends upon the diameter and length of the pipe line, and the velocity and viscosity of the fluids flowing therein. The quantitative relationships between these variables is an interesting problem, of considerable value in the design and operation of product pipe lines.

The first published investigation on contamination in pipe lines was reported in 1911 by Schoder,[7] who studied the mixing taking place between heavy and light oils and between a dye solution and water when flowing successively through a 6-in. line. Schoder concluded from his limited experiments that the volume of the contaminated portion appeared to be a constant percentage of the total volume of the pipe line.

In 1927 it was reported[1] that a slug of natural gasoline had been pumped through a 4-in. crude oil pipe line 90 miles in length with a small amount of mixing between the two materials.

The construction of a products pipe line by the Phillips Petroleum Company in 1931 resulted in several articles[2,3,8] discussing this pipe line, with the prediction based on experiments in a 3-in. line of 24 miles[8] that the amount of mixing expected would be a few hundred barrels in an 8-in. line of 700 miles.

In 1933 Kashcheev[5] reported data on the mixing of gasoline and kerosine pumped through a pipe line extending from Baku to Batum. The flow was intermittent and the use of water-sealed reservoirs at all pumping stations complicated the problem. However, Kashcheev presented two conclusions. First, that the amount of the contaminated portion will not increase proportionally to the length of the pipe. Second, that the greater the diameter and the slower the flow, the greater the amount of contaminated material obtained.

▼ **Theoretical discussion.** ***Viscous flow.*** Viscous flow in a pipe is characterized by a parabolic velocity distribution curve and a direction of motion at any point in the pipe that is always parallel to the axis of the pipe. If two adjacent fluids are flowing one behind the other through a pipe under ideal viscous flow, the interface will remain distinct, provided diffusion takes place to a negligible extent. Fig. 1 presents diagrammatically the interface between fluid *A* followed by fluid *B* in laminar or viscous flow as seen in a cross-section through the pipe.

Assuming diffusion is negligible, it is possible to derive‡ the following equation for the theoretical amount of contamination obtained when the fluids are in viscous flow. Contamination portion as fraction of pipe volume =

$$\frac{1}{2}\left[\frac{1}{(x_2)^{1/2}} - \frac{1}{(x_1)^{1/2}}\right] \quad . \quad . \quad (12)$$

The contaminated portion given in this equation is the volume of fluid collected during the time that the instantaneous composition changes from x_1 to x_2. Instantaneous composition, x, is the instantaneous volume of fluid *A* divided by the instantaneous total fluid volume. The average composition (x) of the contaminated portion collected over the instantaneous composition range x_1 to x_2 can be expressed as:

$$\bar{x} = (x_1\, x_2)^{1/2} \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Table I gives the volume of the contaminated portion collected between the indicated instantaneous compositions as a percentage of the total pipe volume as computed from equation (12), and the average composition of the collected portion as computed from equation (15).

TABLE 1—Theoretical contamination in viscous flow

Range in instantaneous composition while collecting contaminated portion in per cent by volume of leading fluid	Volume of contaminated portion in per cent of total pipe volume	Average composition of contaminated portion expressed as per cent leading fluid
60—40%	14.5%	49.0%
70—30	31.5	45.8
80—20	55.8	40.0
90—10	105.3	30.0
95— 5	172.3	21.8
98— 2	303.0	14.0

It is interesting to see that theoretically the amount of contamination is proportional to the length of pipe and is independent of Reynolds number, provided the flow is in the viscous region.

Turbulent flow. In turbulent flow the velocity of any particular particle is chaotic. It is not constant in either direction or magnitude. Thus the interface between two fluids pumped in succession in turbulent flow does not remain distinct, but is immediately destroyed. If two fluids move successively a distance through a pipe in turbulent flow, a mixture of the two fluids is found separating the pure fluids.

The mixing of pure fluid *B* with a quantity of a mixture of *A* and *B* will result in less contamination of the fluid *B* than if it had been mixed with the same quantity of pure fluid *A*. Therefore the presence of the mixture between the two fluids serves as a buffer decreasing the amount of contaminated portion delivered by the pipe. If this reasoning is sound, an increase in turbulence would decrease the contaminated portion. The quantitative effect of turbulence on the contaminated portion is probably indicated by its effect on the velocity distribution curve[6] and is probably greatest at the lower Reynolds numbers.

▼ **Experimental work.** Most of the experimental data were obtained using dilute salt solutions (0.139 *N* NaCl) and water as the two adjacent fluids flowing through a glass tube. Dilute salt solutions have viscosities and densities nearly equal to those of pure water. Mixtures of the salt solution and water are easily analyzed. The approach of the contaminated portion to the end of the glass tube could be observed by coloring one of the streams by the indicator, potassium chromate, used in the titrations.

Glass tubing was selected for experimental work because it constitutes a smooth tube of low relative roughness, comparable to commercial pipe lines, and it permitted visual observations of the mixing and enabled the sampling to be started at the proper instant.

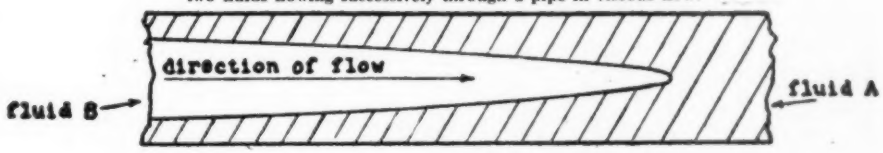
Glass tubes of 0.124 in. and 0.313 in., and lengths varying from 5 ft. to 105 ft. were employed. A three-way stopcock provided a ready method of introducing the following liquid directly behind the leading liquid. Both liquids were supplied from constant-head tanks. For high velocities, air pressure was supplied to the top of the constant head tank containing the following liquid.

The fluid stream, upon leaving the end of the tube, was caught in a series of beakers in a cart that was moved past the end of the tube at constant velocity by winding a wire, attached to the cart,

(*Continued on Page 124*)

‡Derivation given in appendix.

Fig. 1. Diagrammatic representation of the interface between two fluids flowing successively through a pipe in viscous flow.



*Presented before American Association of Chemical Engineers, New York City, May 10-11, 1943.

†Fowler is with Phillips Petroleum Company and Brown is on faculty of University of Michigan.

Then he said to himself

"A War Measure of First-Class Magnitude"

WHEN the standing of India was occupying the attention of Washington, Mohandas Karamchand Gandhi wrote to the India League of America:

> "I want you to look upon the immediate recognition of India's independence as a war measure of first-class magnitude."

For a man so definitely non-Hollywood in dress or words "FIRST-CLASS MAGNITUDE" amounts to a cataclysmic pronunciamento.

Again it shows that one who is fired by a great idea automatically adds emphasis to enthusiasm! And *that* is an important business measure.

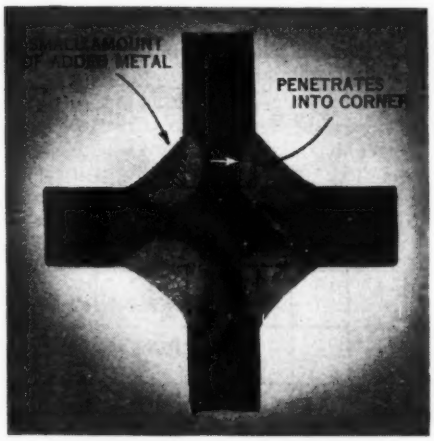
You saw it well illustrated when war conversion was hurled at manufacturers . . . and when "impossible" schedules were handed them.

Men were far from enthusiastic. Remember?

But viewed in the light of subsequent experience, those quotas for air, land and sea weapons today seem modest. All because aroused men quickly found out first-hand what Arc Welding could do. And when it did the job well, they became enthusiastic . . . which brings triumph to any front.

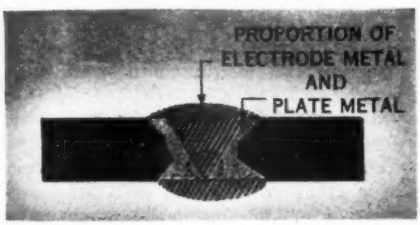
"A War Measure of First-Class Magnitude"...he says

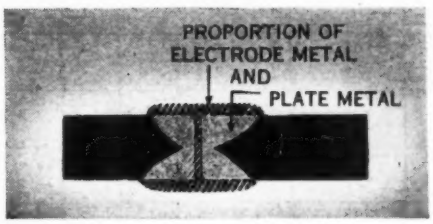
CONVENTIONAL WELDING **"FLEET-WELDING"**



TYPICAL FILLET WELDS

STRENGTH:	**Stronger than plate**	**STRENGTH:**	**Stronger than plate**
SPEED:	**5" per min.**	**SPEED:**	**12" per min.**
COST:	**100%**	**COST:**	**42%**





TYPICAL BUTT WELDS

STRENGTH:	**Stronger than plate**	**STRENGTH:**	**Stronger than plate**
SPEED:	**2" per min.**	**SPEED:**	**9" per min.**
COST:	**100%**	**COST:**	**25%**

LOOK, MAHATMA: While you pondered on the magnitude of political measures for winning, Lincoln Engineers were enthusiastically working out a very practical measure that is away out in front in magnitude:

"FLEET-WELDING"

A First-Class Production Measure ... of First-Class Magnitude

This new, revolutionary technique using "ARC-FORCE" to speed the welding of all types of joints in plate, shapes and sheet is bringing back reports of 25% to 75% faster welding . . . also savings in electrode material and power. Cases also are reported where back-chipping and plate beveling are eliminated.

The savings shown at left are typical of this new technique developed by Lincoln engineers.

A Lincoln engineer is available nearby to help you apply "Fleet-Welding" Technique. Write for Bulletin No. 440 which gives complete explanation of the simple technique and the welding procedures.

THE LINCOLN ELECTRIC COMPANY
CLEVELAND, OHIO

America's greatest natural **recourse**

ARC WELDING

(*Continued from Page 121*)

upon a drum revolved by an electric motor.

The cart containing the beakers was placed in position. The glass tube was then filled with the leading liquid, its temperature recorded, and the desired pressure applied to the constant-head tank, containing the following liquid. Then the run was started by turning the stopcock to the following liquid. Since the water was colored, the contaminated portion could be observed as it moved down the glass tube. Just before it reached the end of the tube, the cart was started, causing the liquid leaving the tube to fall into the beakers. The time during which the beakers collected liquid was recorded by a stopwatch. The temperature of the following liquid was taken after the samples were collected.

In order to determine what, if any, effect variations in the operation of the stopcock might have on the results, in some runs after the tube was filled with leading liquid the end of the tube was closed by a cork and the stopcock was turned to the following liquid. The time interval between turning the stopcock and removing the cork to start the flow was varied. These variations produced no noticeable effect.

Most runs were made using 23 beakers. Several beakers, usually five, were selected from the group of beakers and weighed. This gave the quantity of liquids in these beakers, which usually agreed within 7 per cent. The average content of these five beakers was considered to be the content of each beaker. The saving in time and evaporation losses was considered to justify such a procedure. The contents of each beaker were titrated with $AgNO_3$, using K_2CrO_4 as the indicator to determine the salt content, from which the compositions in terms of the leading fluid were computed.

TABLE 2—Experimental data on salt solution and water

Tube diameter = 0.79 cm. (0.313-in.)
Length = 627 cm. (20.56-ft.)
Volume of tube = 310.5 cc.

Run No. 62

Total elapsed time for 23 beakers = 6.1 sec.
Temperature (leading fluid) = 77° F.
Temperature (following fluid) = 77° F.

Beaker No.	Volume of sample—cc.	Composition of sample, per cent leading fluid
1	10.33	98.5
2		spilled
3		100.3
4		100.2
5		100.0
6	10.38	95.4
7		76.7
8		45.8
9		22.0
10		10.6
11		5.12
12	10.30	2.92
13		0.73
14		0.37
15		0
16		0
17		0
18	10.34	0
19		0
20		0
21		0
22	10.45	0
23		0
	Average vol. = 10.36	

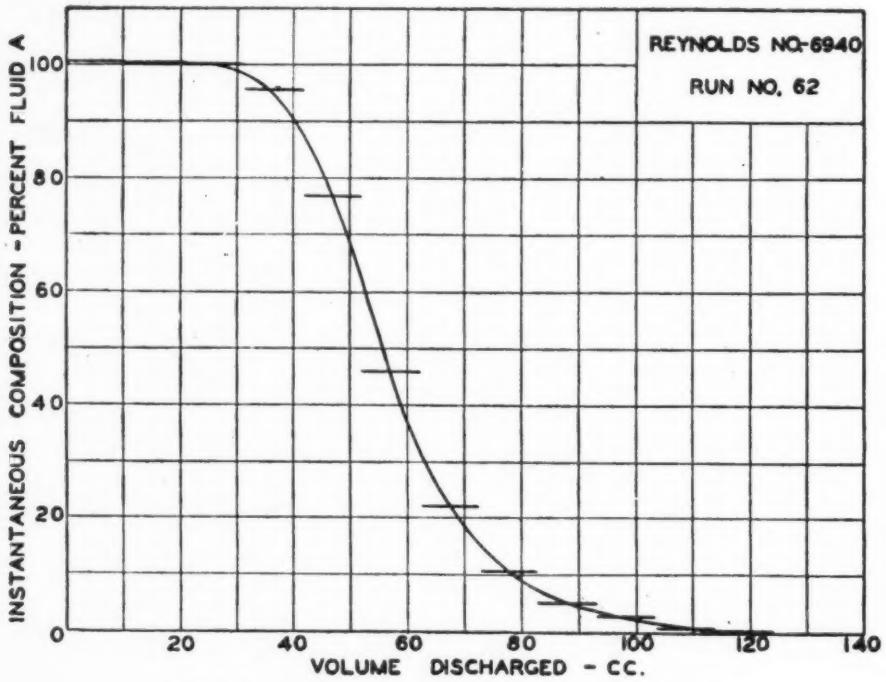
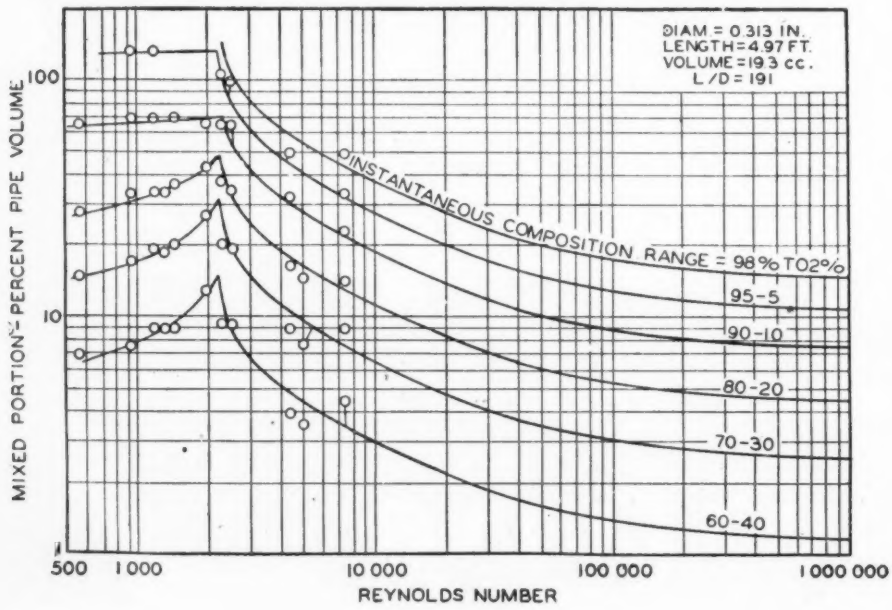


Fig. 2. Instantaneous composition of fluid discharging from end of pipe line plotted against the volume of total fluid discharged.

Fig. 3 through Fig. 9 (inclusive)—The contaminated portion expressed as a percentage of entire pipe volume plotted as a function of Reynolds number. Each line represents the volume of contaminated portion collected between the instantaneous composition range indicated.



Errors. Temperatures of the fluids were read to 1° F., on a mercury-glass thermometer, and are accurate within 2° F. This corresponds to a maximum error of 3 per cent in the viscosity or Reynolds number. The titrations were sensitive to contaminations of 1 per cent of the salt solution in the pure water.

Probably the greatest error is in measuring the quantities of contaminated material leaving the end tube. Spillage in flowing into the beakers, and variations in the diameters of the beakers introduced errors of about 3 and 4 per cent, respectively. Except in those few runs when the samples may have been collected before the beaker carriage attained uniform speed, the error is probably about 7 per cent in the quantity of contaminated material and 3 per cent in Reynolds number. This estimate is confirmed by the fact that most of the data points agree within 10 per cent of the leveled data as represented by the curves in Figs. 3 to 9.

Results. The observed data for each run were recorded as indicated in Table 2 for Run 62. The average volume in each beaker is 10.36 cc. The average composition of each beaker was plotted over a volume increment of 10.36 cc., and the differential curve of instantaneous compositions was then drawn as shown in Fig. 2. Velocity was calculated using the quantity of liquid collected and the time for collection. (23×10.36) or 238 cc. were collected in 6.1 seconds; thus the velocity $= \frac{20.56 \times 238}{310.5 \times 6.1} = 2.58$ ft. per sec. since

volume of the 20.56-ft. glass tube was 310.5 cc. At 77° F. the viscosity of water and the dilute salt solution is 0.90 centipoises. Thus the Reynolds number is

$$\frac{0.313 \times 62.4 \times 2.58}{12 \times 0.000672 \times 0.90} = 6940.$$

The mixed or contaminated portion is the volume of the mixture, collected between the indicated instantaneous composition limits, expressed as a percentage of the total pipe volume. For example, the expression 98 per cent-2 per cent mixed portion is the volume of mixture that flowed from the pipe during the time that the composition changed from 98 per cent leading liquid to 2 per cent leading liquid, expressed as per cent of the total volume of the pipe.

The 98 per cent-2 per cent mixed portion for Run No. 62 is calculated from Fig. 2. The volume between compositions of 98 per cent and 2 per cent leading liquid was equal to 70.5 cc. Since the total volume of the tube was 310.5 cc., the 98 per cent-2 per cent

$$\text{mixed portion} = \frac{70.5}{310.5} = 22.7 \text{ per cent}$$

of the tube volume. Similarly the mixed portion was calculated for other composition changes such as 60 per cent-40 per cent, 70 per cent-30 per cent, etc.

Experimental results are summarized in Table 3. In all runs except Run 55 the salt solution is the leading fluid.

▼ **Effect of diameter, length, velocity, and viscosity.** The contaminated portions for the various composition changes are plotted against the Reynolds number for each particular tube in Figs. 3-9, which give graphically the effect of diameter, velocity, and viscosity on the quantity of the contaminated portion. In the turbulent region these curves are parallel and clearly indicate that an increase in Reynolds number causes a decrease in the contaminated portion.

The curves were drawn through the experimental data on salt solution and water for Reynolds numbers up to 20,000, and were extended to Reynolds numbers of 1,000,000 using commercial data.[9]

In the viscous region theory and experimental data on the longer tubes show that the contaminated portion does not vary with Reynolds number. The apparent increase in the contaminated portion with Reynolds number in the short tubes is attributed to the greater influence of end effects in these tubes.

In all cases the quantity of the contaminated portion is most sensitive to the Reynolds number in the turbulent region near the critical value of about 2200.

Allowing the two liquids to remain in stationary contact with each other before flowing through the tube had no effect on the amount of contaminated portion. Because of the similarity in physical properties of the water and salt solutions, the amount of contaminated portion is the same whether the salt solution or water is the leading fluid. With

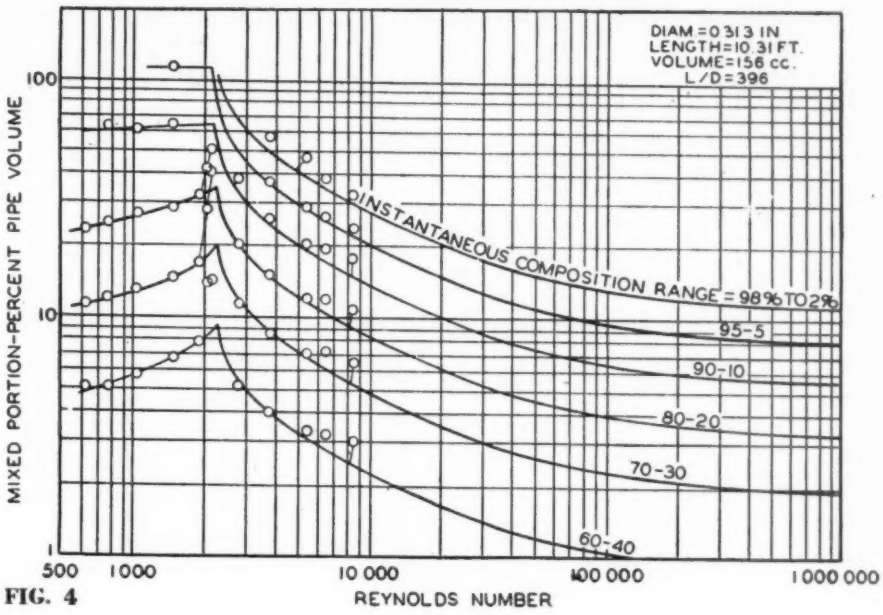


FIG. 4

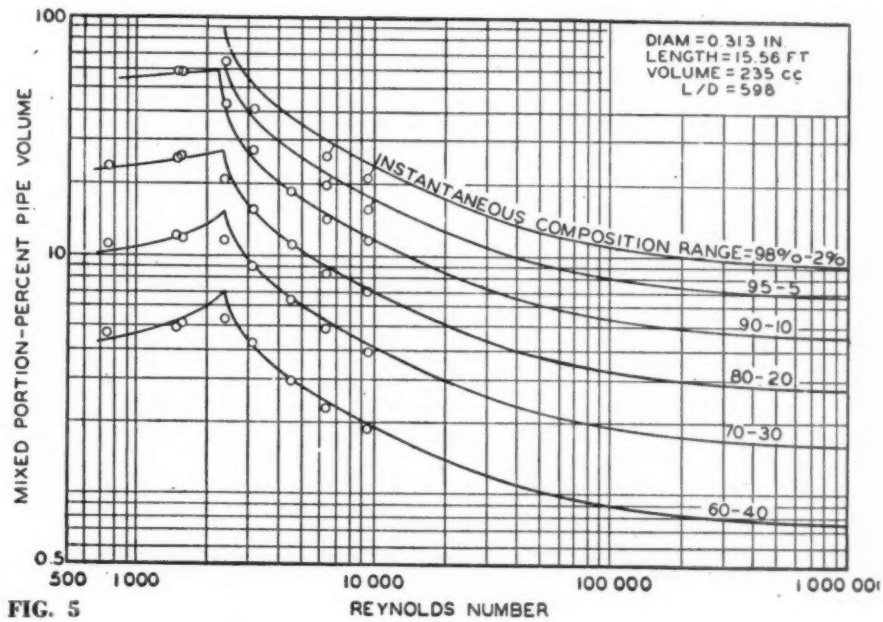


FIG. 5

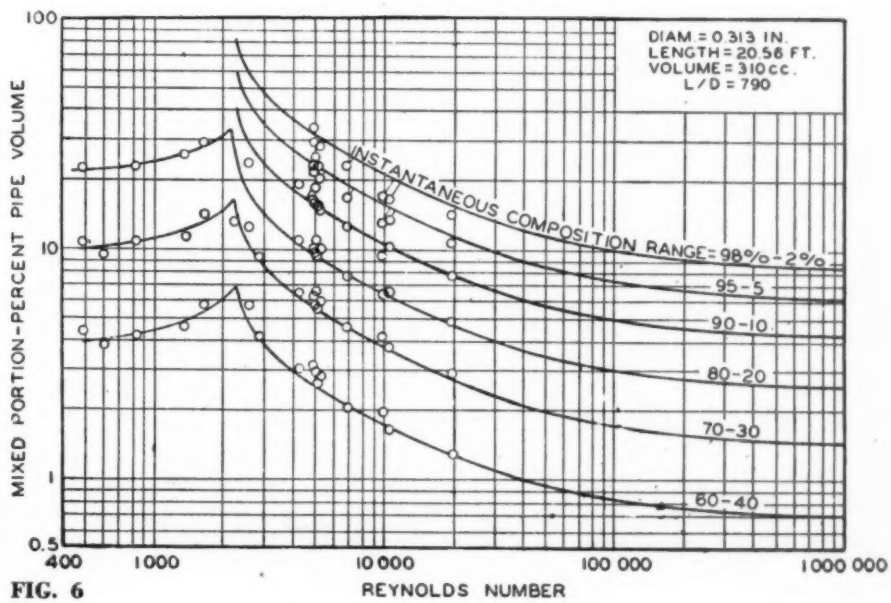


FIG. 6

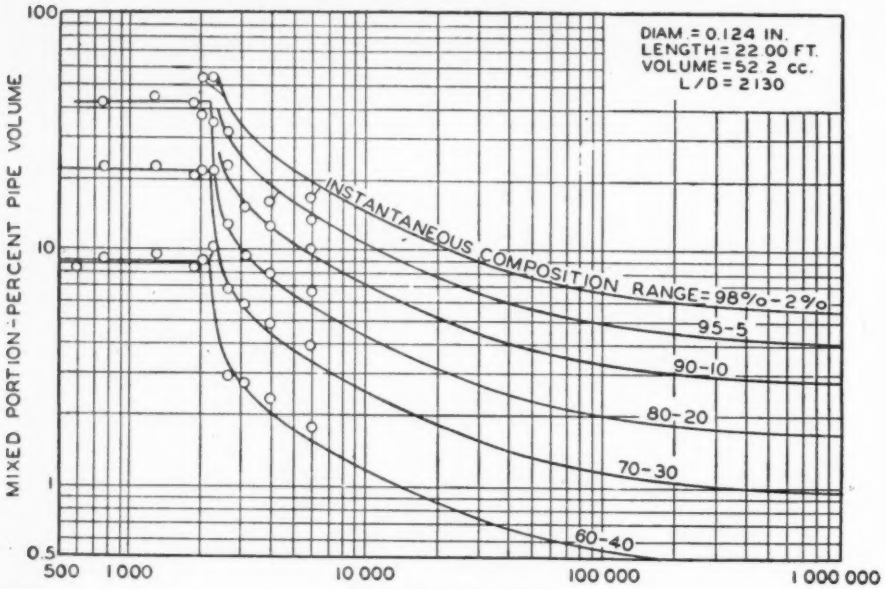


FIG. 7

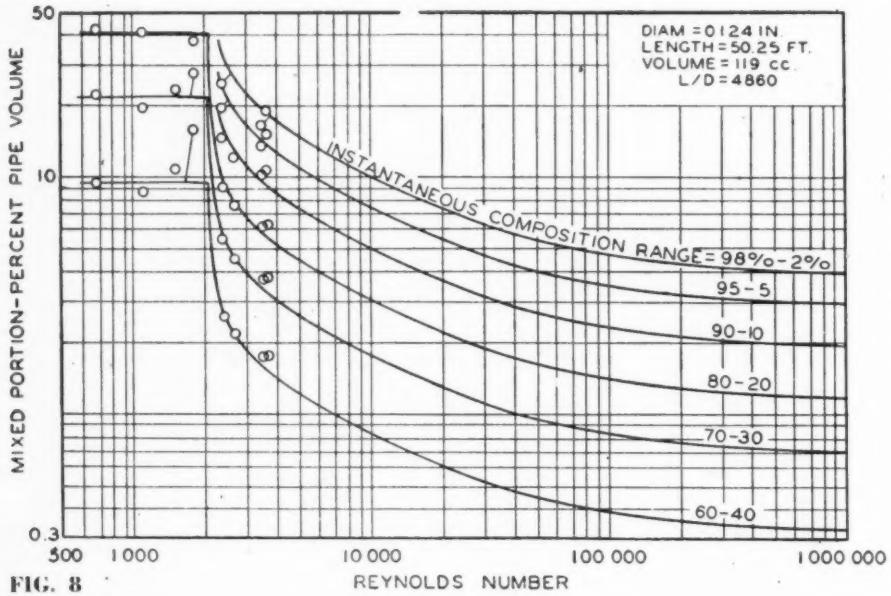


FIG. 8

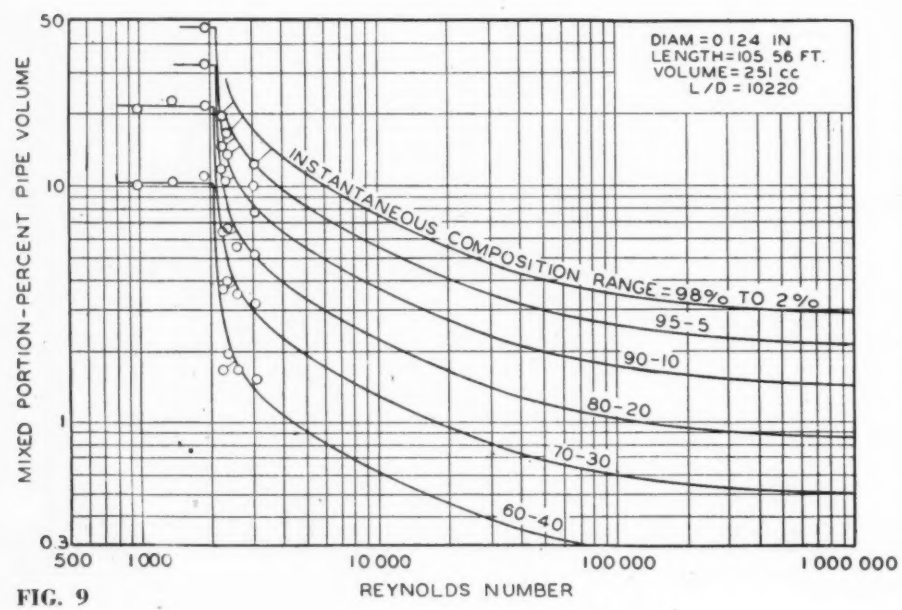


FIG. 9

fluids of dissimilar physical properties this would probably not be the case.

When the contaminated portions for the same change in instantaneous composition in turbulent flow are plotted versus the ratio of length to diameter of the pipe $\left(\frac{L}{D}\right)$, a series of straight lines, having a slope of negative 0.4 are obtained (Fig. 10) for each Reynolds number.

The equation of these lines is:

$$\log_{10}\left(\frac{\text{vol. of contam. portion}}{\text{volume of pipe}}\right) = C - 0.4 \log_{10}\left(\frac{L}{D}\right) \quad . \quad . \quad (19a)$$

or: $\log_{10}$ (contaminated portion) = $\log_{10}$ (pipe vol.) $- 0.4 \log_{10} \times \left(\frac{L}{D}\right) + C$ . . . . . (19)

in which C is a function of the Reynolds number and the range in instantaneous composition covered by the contaminated portion.

Values of C for use in equation (19) for turbulent flow are given in Table 4 and plotted in Fig. 11, as a function of Reynolds number and range in instantaneous composition.

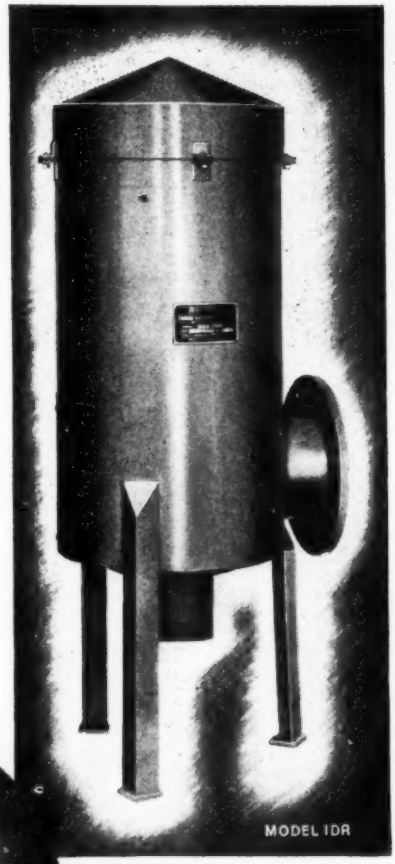
▼ **Discussion.** In comparing the experimental results in the region of laminar flow (Reynolds number less than 2100), Figs. 3-9, with the theoretical quantities of contaminated portion computed for ideal laminar flow as listed in Table 1, it is observed that the experimental contaminated portion in the longer pipes is independent of Reynolds number as indicated by the theoretical considerations, although the numerical value is somewhat less, being about 70 per cent of the theoretical. In the shorter tubes, where end effects are of greater significance, the experimental contaminated portion is not independent of Reynolds number and the numerical value differs even more from the theoretical, being about 50 per cent of the latter.

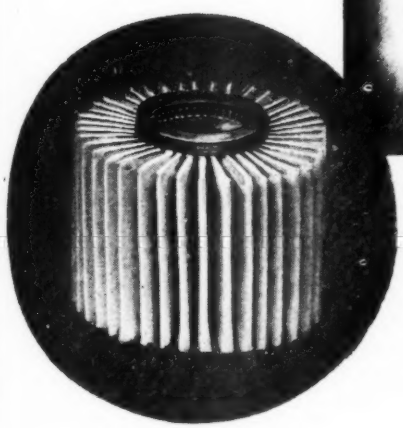
As has been indicated, both theoretically and experimentally, any increase in the turbulence of flow tends to decrease the contaminated portion. It is known that an appreciable time or distance is required to establish true laminar flow. Therefore, the cause for the experimental contaminated portion being less than the theoretical in laminar flow is probably incidental turbulence, or mixing, and end effects.

The work to date has been limited to two successive fluids of identical kinematic viscosity. Lacking any information on the effect of differences in the viscosity of the two fluids, the contaminated portion may be estimated by averaging the kinematic viscosities (or Reynolds numbers) of the two fluids for use in equation (19) or corresponding charts.

▼ **Commercial application.** The contaminated portion in commercial petroleum product pipe lines is an important consideration in their construction and operation. The laboratory data reported in this paper are limited to contamination of two products of the same physical properties. Somewhat different rela-

new STAYNEW Intake Air Filter





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NOW you can equip compressors and internal combustion engines with a Staynew filter providing all the recognized advantages of the famous Protectomotor line . . . *plus* an exclusive combination of two new features.

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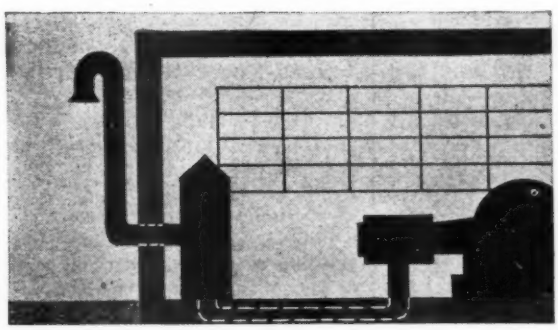
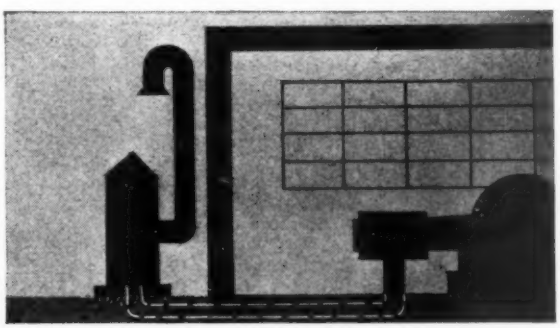


Model IDR INSIDE Engine Room



Model IDR OUTSIDE Engine Room

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tionships are to be expected when dealing with the contamination of dissimilar fluids. However, it appears that the use of equation (19) with the average Reynolds number of the two fluids approximates the contamination in commercial pipe lines[9] as indicated in Table 5 within the indicated error in sampling and analyzing the oil samples.

Samples were withdrawn from the flowing oil stream through a small tap on the pipe line, at 2-min. intervals for a period of about 10 to 15 min., and analyzed by the pipe line operators to the extent of taking A.P.I. gravities by hydrometers. This leaves complete uncertainty as to the range of instantaneous compositions of the stream in the pipe line for a contaminated portion and thus the ranges of 98 per cent-2 per cent and 95 per cent-5 per cent chosen as the basis of comparison must be regarded as arbitrary in making the comparisons in Table 5.

TABLE 3—Experimental results

Run No.	Velocity, ft. per sec.	Viscosity, centipoises	Reynolds number	60-40 per cent mixed portion, per cent	70-30 per cent mixed portion, per cent	80-20 per cent mixed portion, per cent	90-10 per cent mixed portion, per cent	95-5 per cent mixed portion, per cent	98-2 per cent mixed portion, per cent
Diameter=0.313-in., L/D=191, Viscosity=0.90 centipoises									
137	0.214		577	6.93	14.9	27.6	65.3		
127	0.353		951	7.47	17.1	32.9	68.0	132	
126	0.440		1186	8.94	19.2	33.6	68.0	131	
134	0.495		1334	8.80	18.7	33.3			
135	0.537		1450	8.94	20.0	36.0	68.8		
136	0.732		1970	12.80	26.7	42.4	66.1		
128	0.854		2300	9.34	20.4	37.6	63.8	104.7	
129	0.940		2540	9.34	19.2	34.0	63.7	98.0	
132	1.645		4430	3.87	8.80	16.28	32.0	49.4	
131	1.870		5040	3.46	7.60	14.67	27.2		
133	2.80		7530	4.40	8.93	14.00	22.9	33.2	49.2
Diameter=0.313-in., L/D=396, Viscosity=0.90 centipoises									
111	0.234		630	5.14	11.6	23.8			
110	0.294		792	5.14	12.2	25.1	63.7		
124	0.389		1048	5.73	13.1	27.6	62.1		
112	0.553		1490	6.76	15.0	29.1	66.5	114.4	
125	0.711		1913	7.92	17.1	32.8			
122	0.766		2060	14.1	28.2	43.2			
113	0.805		2170	14.5	41.3	51.8			
115	1.04		2800	5.14	11.58	20.6	38.4		
116	1.41		3800	3.99	8.62	15.12	26.2	37.6	58.2
117	2.02		5440	3.35	7.07	12.15	20.8	29.4	47.7
118	2.44		6570	3.22	7.14	11.90	19.5	26.6	38.7
119	3.21		8630	3.02	6.42	10.80	17.75	23.8	32.8
Diameter=0.313-in., L/D=598, Viscosity=0.90 centipoises									
109	0.0653		176	3.41	7.66				
100	0.281		757	4.68	11.08	23.4			
103	0.550		1480	4.95	12.09	25.6	59.6		
99	0.573		1542	5.15	11.63	26.1	59.2		
102	0.872		2350	5.37	11.40	20.7	43.5	66.1	
107	1.15		3090	4.22	8.95	15.44	27.5	40.7	
104	1.658		4470	2.99	6.52	11.10	18.32		
105	2.33		6280	2.26	4.87	8.27	14.08	19.65	26.0
108	3.49		9380	1.877	3.92	7.03	11.42	15.79	21.1
Diameter=0.313-in., L/D=790, Viscosity=0.90 centipoises									
94	0.182		490	4.34	10.47	22.1			
93	0.228		614	3.76	9.30				
96	0.310		834	4.15	10.72	22.6			
97	0.507		1365	4.44	11.20	25.3			
61	0.617		1660	5.60	13.90	28.7			
60	0.838		2250	12.9					
59	0.972		2610	5.63	12.23	23.0			
58	1.07		2880	4.08	9.02				
56	1.59		4300	2.96	6.32	10.82	18.67		
52	1.84		4960	3.06	6.12	9.92	16.09	23.0	33.5
49	1.88		5070	2.87	5.63	9.66	15.64	21.4	28.4
47	1.89		5090	2.96	6.42	10.75	18.22	24.8	
51	1.93		5190	2.54	5.34	9.14	15.05	22.2	
54	1.97		5300	2.74	5.80	9.43	14.68	20.0	27.4
55	1.97		5300	2.77	5.83	9.88			
62	2.58		6940	2.00	4.42	7.47	12.24	16.60	22.7
66	3.69		9910	1.93	4.02	6.22	9.14	12.75	16.25
67	3.95		10620	1.61	3.64	6.32	10.05	13.20	16.10
98	7.35		19800	1.26	2.80	4.77	7.50	10.38	13.82
Diameter=0.124-in., L/D=786									
185	1.11	1.115	957	11.4	23.4	43.0	99.5	228	306
187	3.64	0.814	4290	4.16	8.30	14.0	21.3	28.0	35.8
186	4.72	0.938	4830	4.16	8.82	14.0	20.2	24.9	29.6
Diameter=0.124-in., L/D=2130									
181	0.606	1.002	580	8.25					
183	0.683	0.866	758	9.02	22.3	41.6			
180	1.39	1.071	1250	9.40	22.1	44.2			
184	1.66	0.878	1820	8.25	20.2	40.9			
178	1.89	0.925	1970	8.81	21.1	36.5	52.8		
179	1.87	0.814	2200	10.17	21.1	34.1	52.9		
177	2.17	0.823	2530	2.88	6.72	12.62	22.4	31.1	37.6
176	2.49	0.803	2980	2.68	5.75	9.21	14.80		
175	3.14	0.795	3790	2.30	4.80	7.87	12.30	15.7	
173	5.17	0.878	5650	1.73	3.84	6.52	9.98	13.1	16.3
Diameter=0.124-in., L/D=4860									
198	1.11	1.505	710	9.50	22.3	42.3			
201	1.56	1.347	1115	8.63	19.7	41.2			
202	1.96	1.251	1510	10.83	23.7				
203	2.44	1.291	1820	45.9	27.5	37.9			
206	3.45	1.392	2380	2.60	5.45	9.05	14.75	19.6	24.9
207	3.97	1.430	2670	2.18	4.53	7.63	12.10		
208	4.03	1.109	3500	1.76	3.69	6.20	10.14	13.6	16.6
209	4.63	1.214	3670	1.76	3.77	6.28	10.70	15.1	18.9
Diameter=0.124-in., L/D=10220									
194	1.17	1.154	975	10.0	20.8				
188	1.47	1.030	1372	10.43	22.5				
191	2.05	1.050	1875	10.95	21.5	32.2	46.3		
192	2.45	1.063	2220	1.67	3.63	6.37	11.64	14.55	19.40
195	2.21	0.918	2320	1.95	3.94	6.50	10.25	13.42	16.55
197	2.74	1.030	2560	1.67	3.46	5.43			
196	3.04	0.962	3040	1.51	3.11	5.02	7.65	9.96	12.10

Sample calculation. To estimate the volume of contaminated product discharged from a 10-in. diam. pipe line 100 miles in length when pumping a distillate of 37° A.P.I. and 7.0 centistokes (48.8 Saybolt seconds) viscosity followed by a kerosine of 43° A.P.I. and 3.0 centistokes (36.8 Saybolt seconds) viscosity at 40° F., the temperature of the fluid in the pipe line, when pumping 1500 bbl. per hour.

$$\text{Pipe line } \frac{L}{D} = \frac{100 \times 5280 \times 12}{10}$$

$$= 633{,}600$$

$$\text{Average kinematic viscosity} = \frac{7.0+3.0}{2} = 5 \text{ centistokes}$$

$$= 5 \times 0.00001076 = 0.0000538 \text{ sq. ft. per sec.}$$

$$\text{Velocity} = \frac{1500 \times 42 \times 0.1337}{3600 \times 3.1416 \times \left(\frac{5}{12}\right)^2}$$

$$= 4.28 \text{ ft. per sec.}$$

$$\text{Av. Reynolds No.} = \frac{D\bar{u}}{\nu} = \frac{10 \times 4.28}{12 \times 0.0000538} = 66300$$

$$\text{Volume of pipe} = 3.1416 \times \left(\frac{5}{12}\right)^2 \times \frac{100 \times 5280}{42 \times 0.1337} = 51{,}300 \text{ bbl.}$$

$$\log_{10} (\text{contam. portion}) = \log_{10} (\text{pipe vol.}) - 0.4 \log_{10} \left(\frac{L}{D}\right) + C \quad . \quad . \quad . \quad . \quad . \quad (19)$$

For Reynolds No. of 66,300 and 98 per cent - 2 per cent portion, from Fig. 11:

$$C = 0.19$$

$$\log (\text{contam. portion}) = 4.710 - 0.4\ (5.802) + 0.19 = 2.579$$

98 per cent-2 per cent contaminated portion = 380 bbl.

Similarly for 95 per cent-5 per cent mixed portion, C = 0.06

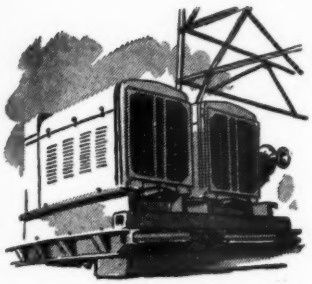
95 per cent-5 per cent contaminated portion = 281 bbl.

▼ **Acknowledgment.** The suggestions and invaluable assistance of Sidney S. Smith and his associates in the Products Pipe Line Department of the Shell Oil Company are gratefully acknowledged.

APPENDIX

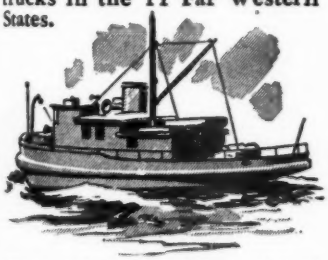
▼ **Derivations of equations for the theoretical amount of contamination in viscous flow.** Assuming diffusion is negligible, it is possible to derive an equation for the amount of fluid A and B that will be discharged from the end of the pipe over any interval of time.

Fluid A is followed by fluid B in viscous flow through a pipe of radius, r, and length, L. The volume flow rate is con-

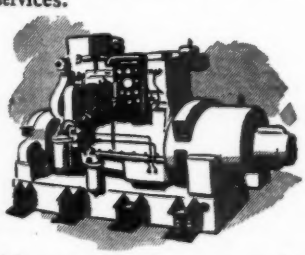


Four Cummins Diesels, three of them seven years old, powered the rig which this year drilled the world's deepest oil well. In this and many other heavy-duty services—logging, construction, and material handling—Cummins Diesels draw the *tough* jobs.

Late in 1932, the world's first heavy-duty, diesel-powered freight truck went into service. The engine was a Cummins Diesel. Today, Cummins Diesels power approximately 90% of all franchise-operated, long-line, heavy-duty, diesel-powered trucks in the 11 Far Western States.



The world's first fully enclosed type marine diesel—now an accepted feature of marine engine design—was built by Cummins in 1928. Cummins Marine Diesels power fishing boats, work boats, pleasure craft and, today, many boats designed for the armed services.



A large part of our expanded production facilities are devoted to the building of Cummins Diesel Generating Sets for the armed services. In peace-time, Cummins Diesel Generating Sets provide low-cost power for mine and mill, factory, farm and municipality.

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The End is Not in Sight

Even a casual comparison of the massive, lumbering diesel of yesterday with a trim, compact, modern-day Cummins Diesel will show that the diesel engine has come a long way in the 26 years that Cummins has been in the business. Yet, the end is not in sight because the same kind of thinking that led to Cummins' development of the original high speed diesel more than a decade ago promises still greater achievements in power efficiency tomorrow. This thinking is characterized by its refusal to become "set in its ways" . . . by its determination to fully explore every possibility for improving design, construction and materials . . . every possibility for giving you still more horsepower per pound and still more profits on your job through high speed diesels. CUMMINS ENGINE COMPANY, INC., Columbus, Indiana.

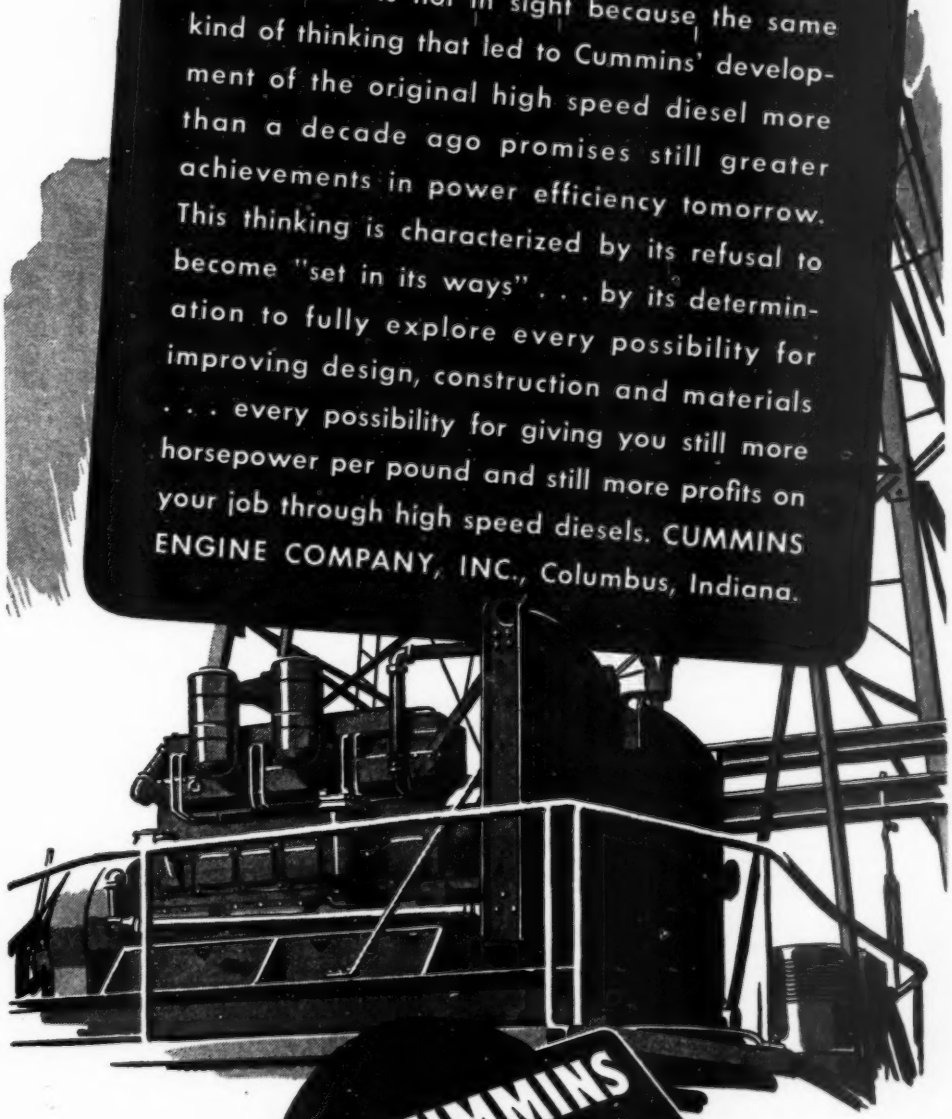

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TABLE 4—Values of factor C to be used in equation (19)

Reynolds number	Instantaneous composition ranges in per cent leading fluid					
	60-40	70-30	80-20	90-10	95-5	98-2
2300	−0.02	0.31	0.55	0.77	0.94	1.07
2500	−0.13	0.20	0.44	0.66	0.83	0.96
3000	−0.25	0.08	0.32	0.54	0.71	0.84
5000	−0.44	−0.11	0.13	0.35	0.52	0.65
10000	−0.61	−0.28	−0.04	0.18	0.35	0.48
20000	−0.74	−0.41	−0.27	0.05	0.22	0.35
50000	−0.87	−0.54	−0.30	−0.08	0.09	0.22
100000	−0.93	−0.60	−0.36	−0.14	0.03	0.16
500000	−1.01	−0.68	−0.44	−0.22	−0.05	0.08
1000000	−1.02	−0.69	−0.45	−0.23	−0.06	0.07

stant and the velocity distribution, Fig. 12, may be represented by the equation:

$$u = u_{max} - \frac{u_{max}}{r^2} y^2 \quad . \quad . \quad . \quad . \quad (1)$$

where u = velocity at distance y from center of pipe, u_{max} = velocity at center of pipe.

Since velocity is constant:

$$u = \frac{L}{t} \text{ or } \frac{dL}{dt} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The composition of the material delivered from the end of the pipe may be expressed as the volume of fluid A delivered divided by the total fluid volume delivered during the same time interval. The instantaneous composition, x, is the instantaneous volume of fluid A divided by the instantaneous total fluid volume.

The diagrammatic cross-section of Fig. 13 indicates the instantaneous discharge of fluids A and B from the end of the pipe during the infinitesimal time interval, dt. By substituting equation (2) in equation (1) and solving for dL:

$$dL = u_{max}dt - u_{max}dt \frac{y^2}{r^2} \quad . \quad (3)$$

The core of fluid B may be considered a cylindrical core over the time interval dt. The instantaneous volume of this center core of fluid B is then:

$$V_B = \int_0^{y_c} (dL)\, 2\pi y dy \quad . \quad (4)$$

Substituting for (dL) from equation (3) and then integrating for a constant time interval (dt):

$$V_B = 2\pi u_{max}(dt)\left[\frac{y_c^2}{2} - \frac{y_c^4}{4r^2}\right] \quad (5)$$

The total instantaneous volume of the fluid discharged in the time interval, dt, is the volume of the paraboloid obtained by integrating equation (4) in the same manner between $y = o$ and $y = r$, or by multiplying the average velocity by the time interval and cross-section of the pipe. By either method:

$$V_{A+B} = \pi r^2 \bar{u}(dt) = \pi r^2 \frac{u_{max}}{2}(dt)$$

$$. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

since the average velocity, $\bar{u}, = \frac{u_{max}}{2}$

in viscous flow. When $y = y_c$, the instantaneous composition,

$$x_c = \frac{V_{A+B} - V_B}{V_{A+B}}$$

$$x_c = \frac{\pi r^2 \frac{u_{max}}{2}(dt) - \pi u_{max}(dt)\left[y_c^2 - \frac{y_c^4}{2r^2}\right]}{\pi r^2 u_{max}(dt)}$$

$$x_c = 1 - 2\left(\frac{y_c}{r}\right)^2 + \left(\frac{y_c}{r}\right)^4 \quad . \quad . \quad (7)$$

Combining equations (1) and (2) and solving for $\left(\frac{y}{r}\right)^2$:

$$\left(\frac{y_c}{r}\right)^2 = 1 - \frac{L}{t_c u_{max}} \quad . \quad . \quad . \quad . \quad (8)$$

Substituting (8) in (7) and simplifying: $x_c = \frac{L^2}{t_c^2 u_{max}^2}$ . . . . . (9)

$$t_c = \frac{L}{u_{max}} \frac{1}{(x_c)^{1/2}} \quad . \quad . \quad . \quad . \quad (9a)$$

The elapsed time for the instantaneous composition of discharge to change from x_1 to x_2 is, from equation (9a):

$$t_2 - t_1 = \frac{L}{u_{max}}\left[\frac{1}{(x_2)^{1/2}} - \frac{1}{(x_1)^{1/2}}\right]$$

$$. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The volume of fluid discharged from the pipe in the time interval $(t_2 - t_1)$ is:

$$V = \pi r^2 \frac{u_{max}}{2}(t_2 - t_1) \quad . \quad (11)$$

Therefore the volume of the contaminated portion between the instantaneous compositions x_1 and x_2 is obtained by substituting the value of $(t_2 - t_1)$ from equation (10) in equation (11).

$$V = \frac{\pi r^2 L}{2}\left[\frac{1}{(x_2)^{1/2}} - \frac{1}{(x_1)^{1/2}}\right]$$

The contaminated portion collected between the instantaneous compositions x_1 and x_2 may be conveniently expressed as a fraction of the total pipe volume by dividing the fluid volume discharged by the pipe volume, $\pi r^2 L$.

Contaminated portions as a fraction of pipe volume

$$= \frac{1}{2}\left[\frac{1}{(x_2)^{1/2}} - \frac{1}{(x_1)^{1/2}}\right] \quad . \quad . \quad (12)$$

The average composition of the contaminated portion collected over the time interval $(t_2 - t_1)$, is equal to the total quantity of material A divided by the total quantity of material collected. The quantity of A collected is obtained by multiplying equation (6) by x and integrating over the time interval. The total quantity of material collected is $\pi r^2 \bar{u}\ (t_2 - t_1)$. Therefore the average composition is:

$$\bar{x} = \frac{\int_{t_1}^{t_2} x \pi r^2 \bar{u} dt}{\pi r^2 \bar{u}(t_2 - t_1)} = \frac{\int_{t_1}^{t_2} x dt}{t_2 - t_1} \quad (13)$$

Fig. 10. Volume of the 60 per cent - 40 per cent contaminated portion expressed as a per cent of total pipe volume plotted against the ratio of length divided by diameter of the pipe for various values of Reynolds number from 2300 to 1,000,000.

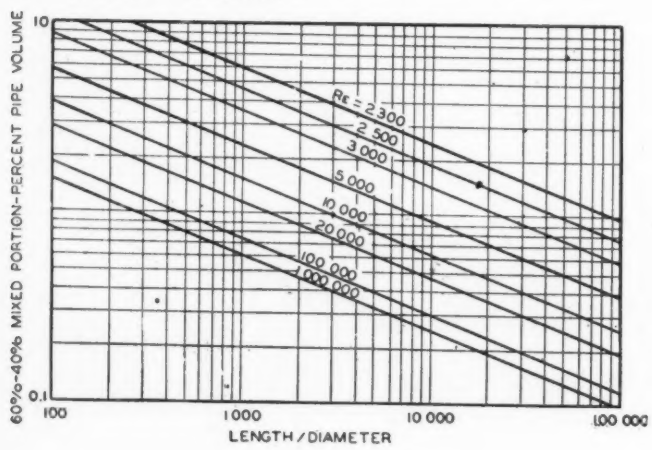
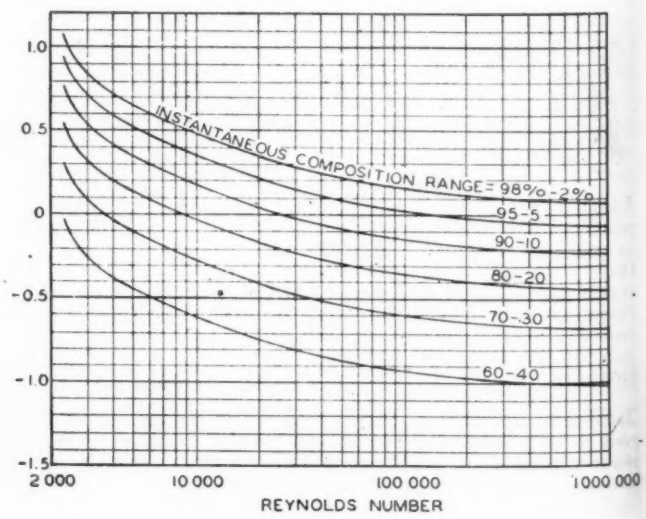


Fig. 11. The value for the factor C to be used in connection with equation (19) plotted as a function of Reynolds number for determining the contaminated portion between the indicated instantaneous composition range.



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• No matter how corrosive or abrasive your substance, there is a combination of alloys that *must* be used for efficient gate valve operation. To help you, this data is published in the interest of maintained production schedules and lower operation costs. It is available to design and maintenance engineers upon request.

General Guide to Materials for Various Services

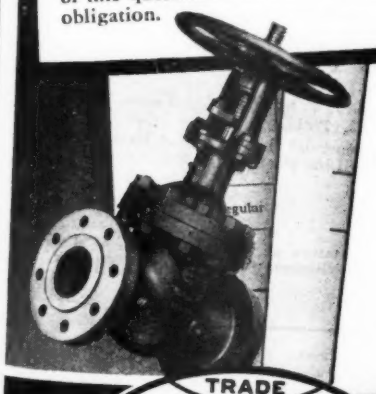
Service	Major Parts	Trim	Pipe and Tubing
Acetic Acid	Ni-Resist, Copper	Special Bronzes, Stainless Monel, High Nickel Chromium	Copper, Monel, Aluminum
Acetone	Brass, Copper	Special Bronzes, Stainless	Copper
Air	Iron, Steel, Brass	" "	Iron, Steel, Brass, Copper
Alcohol	Iron, Steel, Brass, Copper	" "	" " "
Ammonia	Iron, Steel, Ni-Resist, Brass, Bronze, Stainless, Monel	" " "	" " "
Aniline Dyes	I	Monel	
Beer		Stainless, Monel	" "
Brine			
Calcium Chloride			
Carbon Tetrachloride			
Carbonic Acid			
Calcium			

MATERIAL SPECIFICATIONS (METALS AND ALLOYS)

Darling Designation	Nearest A.S.T.M. Specifications	A.S.T.M. Specifications	Type or Name of Metal or Alloy	Form in Which Used	PHYSICAL PROPERTIES: Tensile Strength P.S.I.	Yield Point P.S.I.	Elong. in 2" %	Reduc. of Area %	Brinell Hardness	USES
Daraloy 437		B59-39 Grade A	Special Aluminum-Bronze	Castings	80,000	45,000	18		90	Valve stems, yoke stem nuts, disc facing, pressure castings, hydrant parts, seat rings, etc.
Al.		B26-37	Aluminum	Castings	20,000	7,000	5			Valve parts for certain corrosive services.
		B89-40		Bar Stock	35,000	9,000	16	40		Valve stems for certain corrosive services.
ular			Bolting Material, Regular	Headed Bolts or Studs	60,000	45,000	18	45		Ordinary service
		A96-39	Bolting Material,	Bolt Stud	125,000	105,000	16	50		High temperature and high pressure service.

For that CRITICAL INSTALLATION IN YOUR PLANT

To properly serve users of corrosion resistant valves, Darling Valve & Manufacturing Co. has developed a questionnaire to survey *all conditions* surrounding corrosion problems. Wire or write for your copy of this questionnaire. There is no obligation.



RATED SERVICE PRESSURES FOR ALLOY VALVES

WHEN MADE OVER IRON BODY, U-BOLT, BRONZE OR SPECIALLOY PATTERNS

USE OF CHART

Example—Assume that a 6-inch gate valve, made of Monel and suitable for 150 lbs. cold service pressure is needed. Monel is in Alloy Group C. Under 6-inch valves you find that a Group C valve to meet your needs can be obtained in the 125 lb. Steam, Iron Body pattern, the 150 lb. Steam, Bronze pattern, and the Specialloy pattern.

NOTE—Pressures shown in chart are the same for all sizes of valves in same shaded area.

ALLOY GROUP

A—Darvaliron, Darling 3, 146, and 180 Alloys.
B—Darling 137 Alloy Body and Bonnet, and 437 Alloy Discs.
C—Monel, Darling 96, 97, 302, 410 and 437 Alloys.
D—Aluminum.

Pattern	Regular Rating	Page No.	Alloy Group	SIZE OF VALVE, in Inches: ¼	⅜	½	¾	1	1¼	1½	2	2½	3	4	5	6	8	10	12
				Alloy Rated Service Pressures in lbs. per sq. in. at 100° F.															
IRON BODY GATE VALVES	25 lb. Steam		A B C D											50 125 125 40		50 125 125 40	50 125 125* 40	50 125 125* —	
	125 lb. Steam		A B C D											150 300 200 100		150 300 200 100	150 300* 200 100	150 300* 200 —	
	175 lb. O-W-G		A B C D											175 350 250 —		175 350 250 —	175 350* 250 —	175 350* 250 —	
	200 lb. O-W-G		A B C D											200 400 250 —		200 400 250 —	200 400* 250 —	200 400* 250 —	

TRADE DARLING MARK

VALVE & MANUFACTURING CO.

WILLIAMSPORT, PA.

TABLE 5—Commercial data obtained on a products pipe line of 7.98 in. diameter

(The error in the reported volume of contaminated product is apparently large. For example, in tender 3 the contaminated portion at station 1 is 20 per cent greater than the reported contaminated portion at station 2. This and other discrepancies may be due in part to the lack of definition of the degree of contamination measured, as well as the obvious errors in sampling.)

Tender	°A.P.I.		Viscosity centistokes		Station 1, $\frac{L}{D}$ = 437,000					Station 2, $\frac{L}{D}$ = 910,000				
	Leading fluid	Following fluid	Leading fluid	Following fluid	Average rate, bbl. per hr.	Average Reynolds number	Reported volume contam. product	Volume computed 98 2	Volume computed 95 5	Average rate, bbl. per hr.	Average Reynolds number	Reported volume contam. product	Volume computed 98 2	Volume computed 95 5
1	63.8	78.0	0.64	0.51	950	468,000	114	122	88.6	890	435,000	185	191	138
2	78.0	72.5	0.51	0.67	940	453,000	96.3	123	89.2	900	430,000	112	191	138
3	72.5	78.0	0.67	0.505	1000	481,000	134.5	120	88.1	1030	493,000	112	188	137
4	78.0	62.7	0.505	0.635	1060	522,000	101	119	87.2	1080	532,000	148	186	136
5	42.7	36.5	3.31	5.63	946	62,700	126	159	116	946	62,800	150	246	178
6	36.5	42.7	5.61	3.30	946	62,800	120	159	116	946	62,300	180	246	178
7	36.5	43.6	7.20	2.90	871	59,100	123	162	118	718	47,800	160	260	191
8	42.7	36.5	3.30	7.20	885	54,700	120	165	120	894	54,200	152	255	184
9	78.1	71.7	0.525	0.695	620	288,000	101	126	92.3	687	316,000	130	193	143
10	42.5	36.9	3.15	5.30	958	67,300	128	155	115	948	66,300	119	240	180
11	62.1	42.5	0.645	3.13	958	248,000	160	129	94.4	952	247,000	215	200	146
12	36.9	42.5	5.30	3.15	952	66,900	129	155	115	942	66,000	152	240	180
13	42.5	36.6	3.15	6.75	953	61,500	129	160	117	942	60,700	153	248	182
14	36.6	42.5	6.70	3.15	944	61,000	92	160	117					
15	42.5	63.0	3.15	0.645	934	242,000	272	129	94.4					
16	63.0	77.7	0.65	0.51	1116	544,000	113	119	87.5	1118	519,000	149	186	136
17	77.7	72.0	0.51	0.68	1117	531,000	150	119	87.5	1118	531,000	112	186	136
18	72.0	77.7	0.675	0.51	1121	537,000	145	119	87.5	1121	533,000	150	186	136
					Station 3, $\frac{L}{D}$ = 1,353,000					Station 4, $\frac{L}{D}$ = 1,765,000				
1	63.8	78.0	0.64	0.51	1000	488,000	186	238	174	1010	489,000	293	275	202
2	78.0	72.5	0.51	0.675	1010	533,000	222	237	173	1020	483,000	336	275	202
3	72.5	78.0	0.68	0.51	1020	485,000	224	238	174	1060	501,000	262	274	200
4	78.0	62.7	0.51	0.645	1040	505,000	335	237	173	1080	524,000	412	274	200
5	42.7	36.5	3.35	5.70	946	61,900	211	313	230	883	57,800	331	372	272
6														
7														
8	42.7	36.5	3.35	7.40	823	49,400	205	332	244					

Substituting for x from equation (9):

$$\bar{x} = \frac{\int_{t_1}^{t_2} \frac{L^2}{t^2 u^2_{max}}\,dt}{t_2 - t_1} =$$

$$\frac{L^2}{u^2_{max}(t_2 - t_1)} \int_{t_1}^{t_2} \frac{dt}{t^2}$$

$$\bar{x} = \frac{L^2}{u^2_{max} t_1 t_2} \quad . \quad . \quad . \quad . \quad . \quad (14)$$

Substituting for t from equation (9a):

$$\bar{x} = (x_1 x_2)^{1/2} \quad . \quad . \quad . \quad . \quad . \quad (15)$$

If the instantaneous proportion of fluid A in the entire cross-section of the pipe is desired instead of the proportion of fluid A in the discharge, this may be computed by dividing the cross-sectional area of the pipe occupied by fluid A, by the cross-sectional area of the pipe, or:

$$z = \frac{\pi r^2 - \pi y_c^2}{\pi r^2} = 1 - \left(\frac{y_c}{r}\right)^2$$

Substituting from equation (8) the value for $\left(\frac{y_c}{r}\right)^2$:

$$z = \frac{L}{t_c u_{max}} \text{ or } t_c \frac{L}{u_{max} z} \quad . \quad . \quad (16)$$

The total volume of fluid passing a point in the time interval $(t_2 - t_1)$ is given by equation (11). Substituting for t_1 and t_2 in equation (11) the value from equation (16), the total volume flowing past a point in the pipe between the instantaneous compositions z_1 and z_2 is:

$$V = \frac{\pi r^2 L}{2}\left[\frac{1}{z_2} - \frac{1}{z_1}\right] \quad . \quad . \quad (17)$$

By dividing by the volume of the entire pipe, this volume is expressed as a percentage of the total pipe volume as:

Contaminated portion as a fraction of pipe volume $= \frac{1}{2}\left[\frac{1}{z_2} - \frac{1}{z_1}\right]$. (18)

Nomenclature

A = leading fluid of two fluids flowing successively through a pipe,
B = following fluid of two fluids flowing successively through a pipe,
D = inside diameter of pipe, ft.,
L = distance over which the two fluids flow successively, ft.,
r = inside radius of pipe, ft.,
s = specific gravity of fluids,
t = time starting when the two fluids begin their successive flow, sec.,
u = velocity of fluid at distance y from center of pipe, ft. per sec.,
$\bar{u}$ = average velocity of flow, ft. per sec.,
u_{max} = velocity of fluid at center of pipe, ft. per sec.,
V = volume of fluid discharging from pipe, cu. ft.,
X = inlet station,
x = composition of mixture — volume of fluid A in sample ÷ total volume of sample,
Y = station at distance L from station X,
y = distance a point is from center of pipe, ft.,
p = density, lb. per cu ft.,
u = viscosity, lb. per sec. ft., and
v = Kinematic viscosity, sq. ft. per sec.

"98-2 mixed portion" = volume of liquid discharging from pipe while the composition changes from 98 per cent A to 2 per cent A.

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Fig. 12. Parabolic velocity distribution curve for viscous flow.

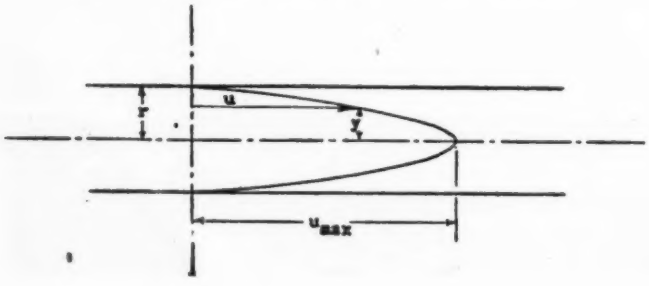
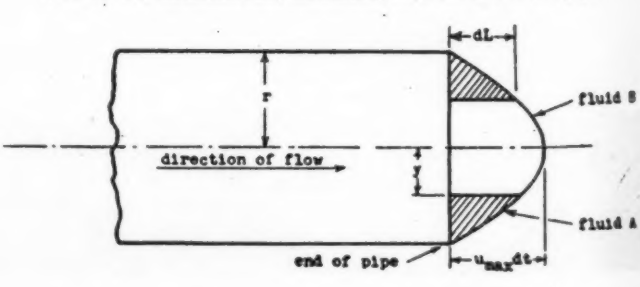


Fig. 13. Diagrammatic representation of the cross-section of fluid (volume dV) instantaneously discharging from the end of the pipe.



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TODAY and TOMORROW
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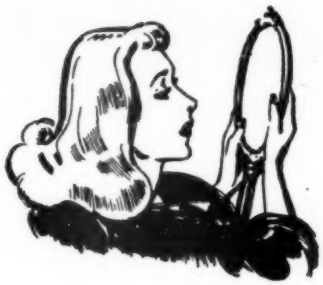

MAKE UP OR BLOW UP

it spells GLYCERIN to the Oil Chemist

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Strange that both, so different in effect, stem from the same source —glycerin, an oil derivative.

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mplete Service for Every Field

DEHYDRATING **DESALTING**

WELDED DRAWWORKS DRUM

EXCLUSIVE Another outstanding example of the trend toward welded design for a large variety of machine parts was signified in the conversion of a cast steel drum to welded fabrication at the plant of a Pennsylvania oil field equipment manufacturer. As reported to The Lincoln Electric Company, the drum, used for hoisting drill pipe in rotary drilling operations, was of cast design (Fig. 1).

The drum is 32¾ in. wide with flanges ¾ in. thick and 38 in. in diameter. The inner hub or core arrangement, consisting of 2 sections varying in length, presents a rather intricate design as indicated in Fig. 1. A number of machining operations are necessary before the drum is pressed on its shaft.

Due to the urgent need of this equipment it was decided to fabricate the drum by arc welding methods so that field operations could proceed on schedule. By turning to welding, the design of the hoist drum was duplicated using various cut and formed pieces.

Speed of fabrication was effected through the use of large, ¼-in. electrode for mild steel having American Welding Society Specifications, E-6012. Fillet welds were used throughout.

A further improvement in the welded drum was later made by increasing the diameter of the flanges from 38 in. to 44 in. to present greater braking capacity. This signifies the flexibility of the arc welding process as no patterns are required as in conventional methods of construction.

The welded design, detailed in Fig. 2 effected a saving of approximately $100 per drum over former cast design. Material used for the welded drum consisted mainly of ½, ¾, and ⅞ in. SAE 1020 steel plate as pointed out by No. 1, 2, 3, 4, 5, and 8 in Fig. 2, with 16-in. seamless casing forming the main hub. The ony casting used in the welded structure was the anchor guide indicated by the number "7" (Fig. 2). Other members were 2 by ¾ by 14¾-in. tapered pieces. See number "6," Fig. 2. ★★★

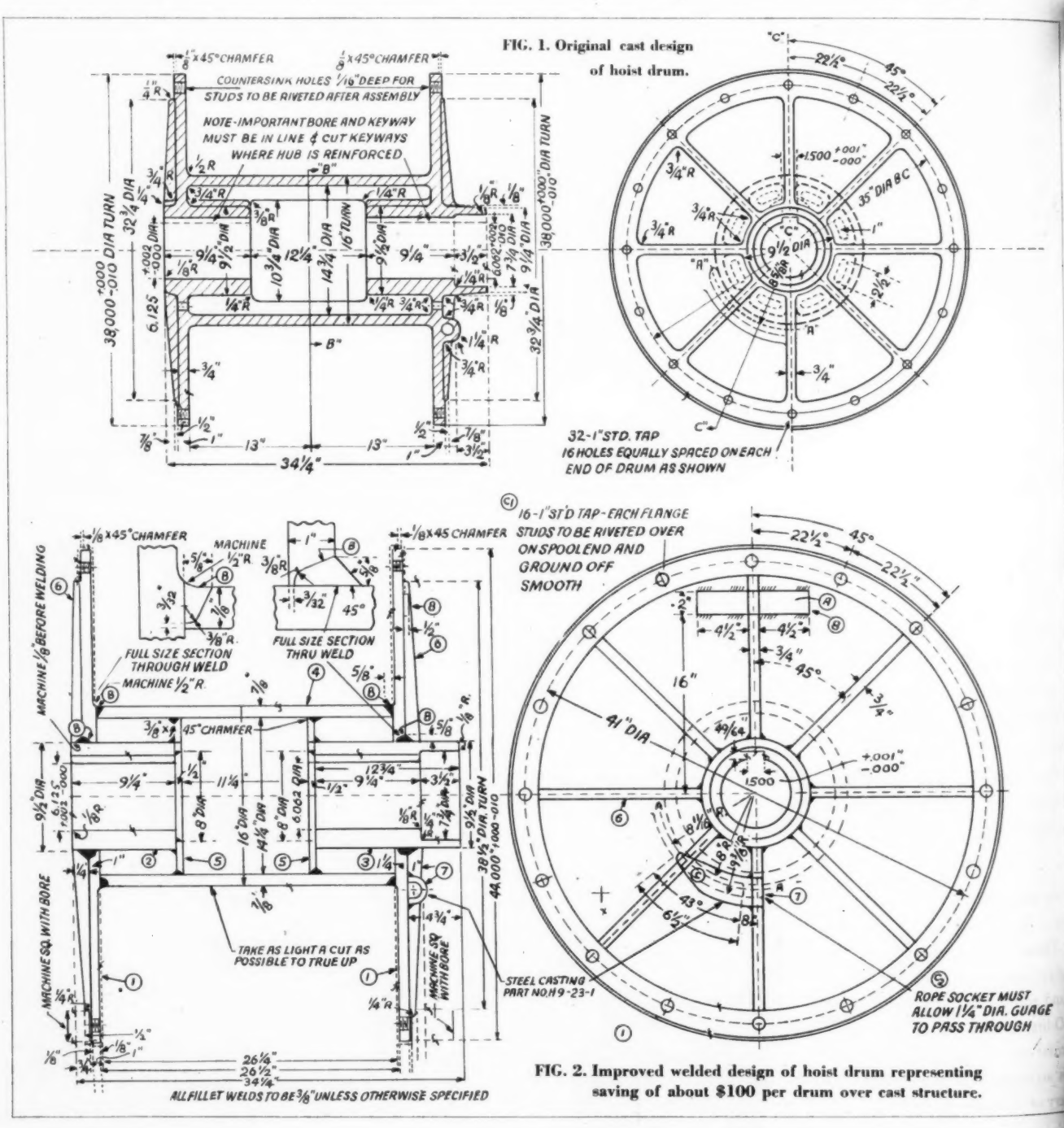
⅛ x 45° CHAMFER
COUNTERSINK HOLES 1/16" DEEP FOR STUDS TO BE RIVETED AFTER ASSEMBLY
NOTE-IMPORTANT BORE AND KEYWAY MUST BE IN LINE & CUT KEYWAYS WHERE HUB IS REINFORCED
38.000 +.000 -.010 DIA TURN
32¾ DIA
34¼"
13"
1"
32-1" STD. TAP
16 HOLES EQUALLY SPACED ON EACH END OF DRUM AS SHOWN
16-1" STD TAP-EACH FLANGE STUDS TO BE RIVETED OVER ON SPOOL END AND GROUND OFF SMOOTH
MACHINE ⅛" BEFORE WELDING
MACHINE ½" R.
FULL SIZE SECTION THROUGH WELD
FULL SIZE SECTION THRU WELD
45° CHAMFER
TAKE AS LIGHT A CUT AS POSSIBLE TO TRUE UP
MACHINE SQ. WITH BORE
STEEL CASTING PART NO. H 9-23-1
ROPE SOCKET MUST ALLOW 1¼" DIA. GUAGE TO PASS THROUGH
41" DIA
16"
26¼"
26½"
34¼"
ALL FILLET WELDS TO BE ⅜" UNLESS OTHERWISE SPECIFIED

FIG. 1. Original cast design of hoist drum.

FIG. 2. Improved welded design of hoist drum representing saving of about $100 per drum over cast structure.

ENTRIES FOR THE

Shafer Achievement Awards

ARE STILL OPEN

SHAFER CONCAVEX SELF-ALIGNING BEARINGS

Reg. U. S. Pat. Off.

As announced nationally in May 1944, the Shafer Achievement Awards are open to engineers, technical or practical men who may have discovered new uses for Shafer Concavex Self-Aligning Bearings or who may have had ideas for the improvement of Shafer Bearing design, manufacture, installation or service.

The Shafer Achievement Awards are prompted by the belief that the ingenuity displayed by the men who use, operate, install or service equipment which has resulted in such amazing technological progress during this war, may have been equally applied to Shafer Bearings. It is apparent that thousands more of such men have had familiar contact with Shafer Bearings during the years of this war. It is equally apparent that in the years to follow, maximum bearing efficiency and dependability will play an enormous role in securing to the new world the benefits of lower costs, of greater machine ingenuity, of greater productiveness. It is to secure such discoveries as they may apply to Shafer Bearings that the Shafer Achievement Awards have been instituted.

All suggestions and ideas will be judged by the following authorities:

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ARTHUR G. WILLIAMS, Vice-President, in charge of Engineering, Shafer Bearing Corporation.

Awards as stated above will be made on the basis of the merit in whatever ideas are submitted as valuable contributions to the art of design, manufacture, application or use of Shafer Self-Aligning Bearings. The opinion of the judges will alone determine the relative merits of any ideas submitted and all decisions of the judges will be final. In the event of any ties, identical or duplicate awards will be made. The Shafer Bearing Corporation reserves the right to adopt or make use of any ideas submitted.

The Basic Shafer Idea

Shafer Concavex Self-Aligning Bearings . . . neither ball nor roller bearings . . . combine the advantages of both . . . utilizing the effective contact area of a ball many times its size . . . yet eliminating such a ball's ineffective mass. Automatic self-alignment, high radial load capacity, superior shock resistance and long life result.

Address all entries to the Shafer Achievement Awards Committee

Shafer Bearing Corporation

1526 W. Washington Blvd., Chicago 7, Illinois

Gun Perforating for Multi-Zone Control in California*

By T. H. WALLACE†

Abstract. The author discusses the application of gun perforating as a routine procedure for completing wells, by demonstrating by combining gun perforating with the proper method of perforation washing, certain objections accepted commonly as inevitable with gun perforating, may be eliminated.

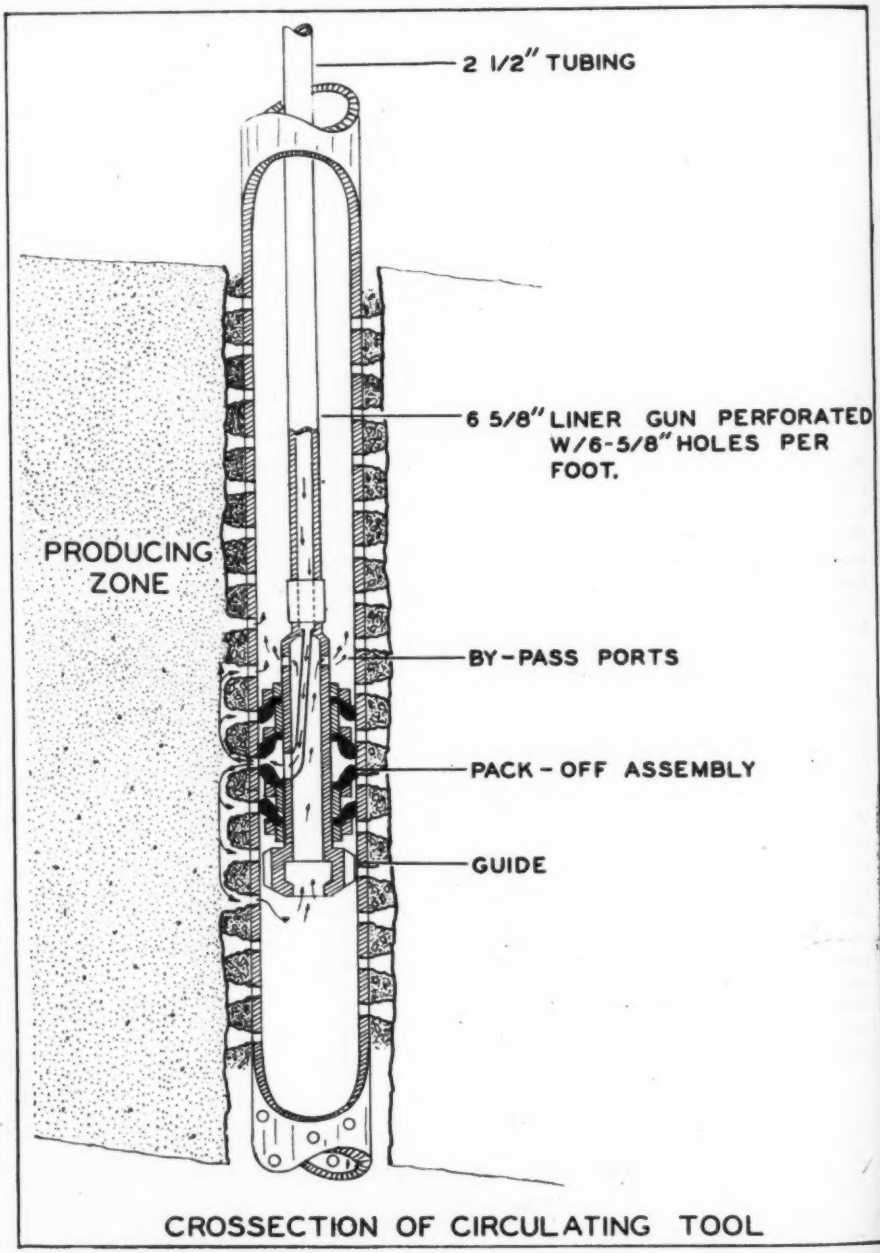
THE use of gun perforating as discussed herein is not an endeavor to sell gun perforating to the oil industry as the only method of completing a well or to advance it as a "cure all" for the many and varied problems encountered in completing and placing a well on production. It is rather a discussion of the use of gun perforating as another "tool" or method used more successfully in coping with the particular problems outlined later than methods which had been used previously. It is entirely possible the use of gun perforating as discussed may be improved upon or will not be the solution to the problems met in each and every field.

In the past, the method of gun perforating was assumed to be something more or less standard and the results accomplished, good or bad, accepted as a matter of course; that is, casing would be cemented through known sands, either because of anticipated deeper production or with the idea of testing one or more zones selectively. The casing opposite the known productive intervals would be gun perforated with one, two, or three holes per foot, of diameters more or less selected at random, and the well placed upon production. If the well produced 5 or 50 bbl. that was it. If the production was as anticipated nothing was thought of it and if it was below normal it was because of the gun perforating. No attempt was made to analyze the situation as to whether a sufficient number of holes had been shot per foot or whether the holes were of the correct diameter and spacing. As a consequence, whenever gun perforating was considered, successful jobs were minimized and the less successful jobs remembered with the result that gun perforating came to be used only in cases of necessity or last resort.

In place of following this line of thought, it was decided to assume, when gun perforating casing opposite a known productive sand, that if the proper number of holes per foot were used of the proper diameter and spacing and all other factors being equal, the results attained by gun perforating should be comparable to those that would have been attained by running a conventional slotted liner, since the principal physical difference was only that in one case there would be round holes as compared to rectangular slots in the other. On this basis then why should not comparable rates of production be established using either method of well completion?

This line of reasoning was prompted by the problem at hand. How to re-work and deepen a large number of old wells in addition to completing new wells through 800 to 1200 ft. of section, having 500 to 600 ft. of net productive sand thickness, divided into 6 principal zones with intermediate shale streaks, making it possible to isolate the individual sand members from the rest of the zone or zones for present and future water control over the respective sand members? In the past, at various times, the cementing of blank sections of pipe between slotted sections of liner had been attempted without too much success in getting anything cemented in place except the perforated intervals and in one case the cementing tools. However, even had these jobs turned out 100 per cent successful it would have been impractical if not impossible to cement sufficient blank sections to obtain the control desired because of the many sand members and the small thickness of certain shale bodies.

It was decided finally to drill one well through several horizons, cement a solid liner in place, and test the sand members individually from the bottom up by gun perforating. The bottom zone of the well selected was gun perforated and the well placed on production. The



CROSSECTION OF CIRCULATING TOOL

Fig. 1.

*Presented before American Institute of Mining and Metallurgical Engineers, Los Angeles, California, October 21-22, 1943.

†Superintendent, Western Gulf Oil Company.

Baash-Ross News

BAASH-ROSS TOOL COMPANY · LOS ANGELES · HOUSTON · NEW YORK

PETROLEUM ENGINEER EDITION

You use ROLLERS to carry the load

in the Crown . . . Swivel . . .

and in the Table!

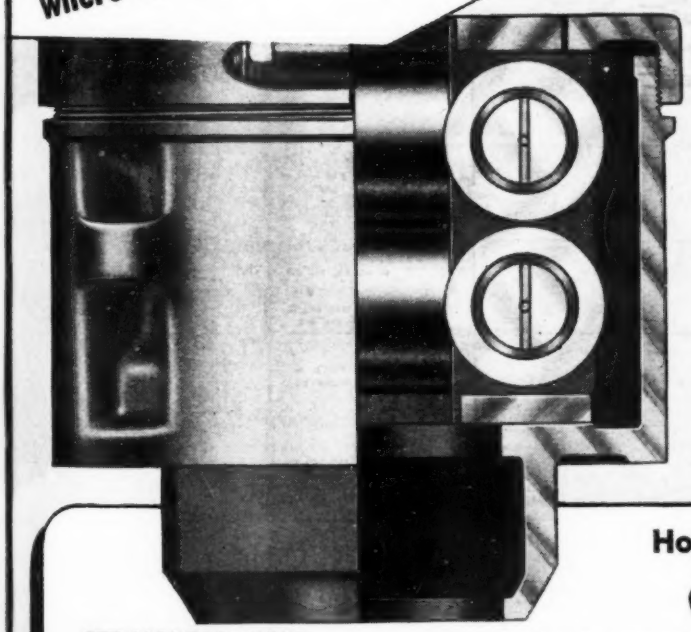
why not HERE

where driving pressures are concentrated?

Why no rig is completely modern

without a

BAASH-ROSS Roller Kelly Bushing!



IT IS sometimes difficult to realize that, although a kelly may easily drop through the bushing when the string is standing still or turning slowly, under the terrific driving pressures set up in spinning thousands of feet of drill string at today's high rotational speeds the kelly will actually "freeze" in the bushing . . . *unless some way is provided of eliminating the friction between kelly and bushing surfaces.*

This is why no other kelly bushing can match the smooth, accurate bit control and friction-free efficiency of the Baash-Ross Roller Kelly Bushing . . . because it is the *only* bushing in which the driving load of rotating the string is carried by multiple free-turning rollers contacting each face of the kelly. *The result—instant, effortless response to the slightest variations in bit feed and control*—which, in turn, pays important dividends in many ways . . .

How the Baash-Ross Roller Kelly Bushing *Pays EXTRA Dividends!*

STRAIGHTER HOLE: Every operator knows the importance of weight control to straight hole. But you get maximum bit control only when the bushing permits the kelly to feed off *instantly* and *smoothly* as weight is applied. This is the kind of quick, accurate bit control you get with the Baash-Ross *Roller* Kelly Bushing!

LONGER EQUIPMENT LIFE: The positive weight control advantages of the Baash-Ross Roller Kelly Bushing are alone sufficient reason for adopting this bushing for all drilling work. But in addition, this bushing prolongs the operating life of *all* your costly rig equipment. By minimizing the surging loads of sudden "feed-offs," the bearings in your rotary table, swivel and blocks are safeguarded against damage, and the life of your drilling line is also greatly prolonged.

FEWER FISHING JOBS: One of the prime causes of twist-offs is the sudden torsional strain produced in the string when drilling weight is fed off too rapidly. By assuring better bit control, the Baash-Ross Roller Kelly Bushing prolongs the life of your drill string and reduces risk of costly twist-offs!

LESS BUSHING MAINTENANCE: In contrast to conventional kelly bushings, maintenance of the Baash-Ross Roller Kelly Bushing is unusually simple . . . just periodic lubrication through the easily reached nipples in the top of the unit. And about the only parts that wear—the roller pins—can be quickly reversed after many thousands of feet of hole to bring the unworn back sides to the front for added trouble-free service!

The above are just a few of *many* advantages in the Baash-Ross Roller Kelly Bushing. For complete details see your nearby Baash-Ross representative. Or write direct!

REMEMBER—no matter how efficient the rest of your rig equipment, unless you carry the driving pressures of rotating your string on friction-free rollers, your rig is not completely modern! Use a BAASH-ROSS ROLLER KELLY BUSHING! Available for both square and hexagon kellys—all sizes.

well was swabbed practically dry with a fluid entry of only 5 to 10 bbl. a day.

Rather than continue any additional tests on this zone on which there was no production history from adjacent wells, it was decided to set a bridge plug above the interval perforated and perforate opposite a higher sand interval that was open to production in the nearby wells completed in the conventional manner with slotted liners. This was done using 300, ¾-in. holes, spaced 4 holes per foot. The well was again placed on production and again the well was swabbed dry. The perforated interval was then pressure washed twice in the conventional manner and the well placed back on production pumping approximately 10 bbl. a day, whereas other wells completed in the same zone using slotted liners were producing about 100 bbl. a day.

It was decided that considerable infiltration of drilling fluid into the sand, followed by a certain amount of cement while cementing the liner in place, had set up a "jell" condition in the vicinity of the well bore and that the conventional perforation washer, operating on a relatively short stroke of the tubing to build up pressure, did not have the fluid capacity to follow through effectively and break down this condition.

As an experiment, an opposed swab assembly or circulating mandrel, see Fig. 1, with the opposed swab cups placed as close to each other as possible, approximately eight inches apart, was run. High pressure pumping equipment, rented from an oil well cementing company, was used to build up the required fluid pressure to break circulation between shot holes outside the liner and to pump the fluid volume desired for washing.

Oil was used as the circulating fluid and after pumping away 15 or 20 bbl. at 1700-lb. pressure circulation was gradually established and the pressure dropped to 350 lb. The whole perforated interval was washed in this manner at the rate of 12 to 15 ft. an hr. Before completing the washing, the returned fluid began to show some gas and the volume of the fluid returns was greater than the volume of the fluid being circulated indicating that the formation was contributing. The circulating mandrel was then pulled, the tubing, pump and rods run and the well placed on production. The well produced at a rate of 150 bbl. of clean oil a day for 10 days before sanding up. The well was again pulled, sand bailed, and the perforations rewashed as described previously and the well again placed on production. Since then, August, 1942, the well has produced continuously producing a total of 42,350 bbl. of net oil as of October 1, 1943, or an average of 105 bbl. a day. At present the well is producing 100 bbl. of net oil a day with 5 per cent water, which is comparable to the production of adjacent wells completed in the traditional manner.

To emphasize the point made previously as to accepting results after gun perforating as final, the history of another well will be outlined briefly.

The particular well in question was plugged back after a test of deeper formations for possible production had been made. During the test, 7-in. casing had been run and cemented through 3 productive sand intervals. These intervals were finally opened to production by gun perforating through the casing, using ⅜-in. diameter shots, spaced on 3-in. centers over a 50-ft. interval. Since the original completion in August, 1940, to September, 1942, the maximum production that had been attained was approximately 15 bbl. a day, which had been taken for granted. During this period the well produced a total of only 9947 bbl. of net oil.

In September, 1942, after the success in the well discussed previously, it was decided to reperforate the interval already open to production and 70 ft. more with an additional 480, ⅜-in. diameter shots on 3-in. centers. The well was washed thoroughly as heretofore described and placed on the pump during the latter part of September, 1942. Since then to October 1, 1943, the well has produced a total of 28,118 bbls. of net oil, or an average of better than 75 bbl. daily. On the basis of the performance of the well prior to reperforating, it would have been expected that the production increase would have been proportional to the amount of additional interval perforated or approximately 18 bbl. a day, or a total production of 30 bbl. a day from the well. The actual increase was 150 per cent greater than would have been expected for the additional interval perforated and the overall production of the well was increased 600 per cent.

The procedure now followed in com-

(Continued on Page 144)

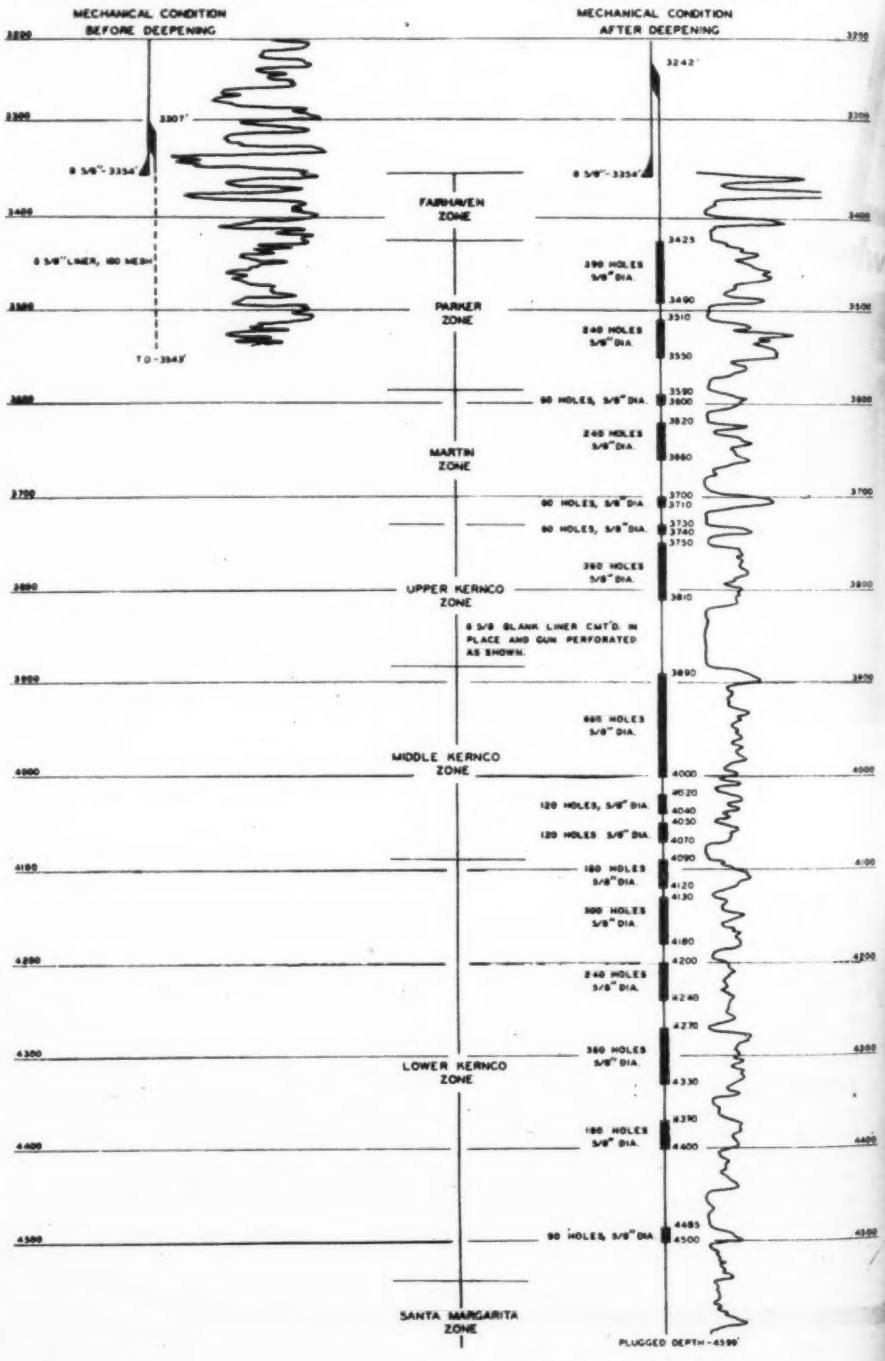
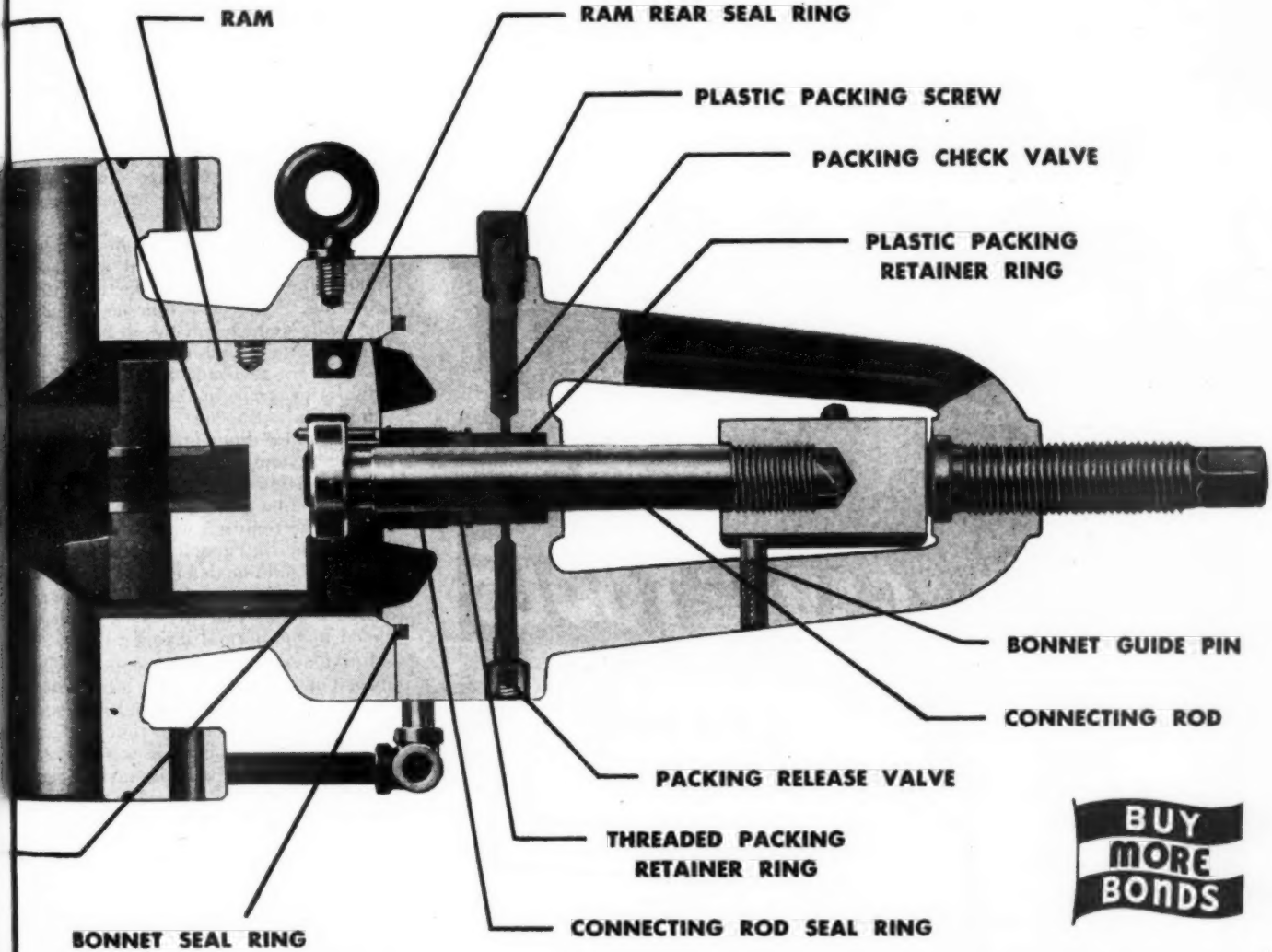


Fig. 2.

Ram Change

NEW CAMERON PRESSURE-OPERATED BLOWOUT WILL PAY FOR ITSELF IN RAM CHANGING TIME ALONE



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While the above comprise the most noteworthy features of Cameron Type "QRC" Blowout Preventers, still other mechanical improvements have been added to assure long, trouble-free operation under the most severe conditions. In addition to these, such proven features as: Patented Self-Feeding Ram Packing, oversize bore to permit the passage of casing and tubing hangers, self-centering rams which automatically center the pipe in the hole, round ram bore in which cuttings cannot accumulate and prevent full closure of the rams, and others combine to make the Type "QRC" Cameron's greatest achievement in drilling control equipment.

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(Continued from Page 140)

pleting redrilled and new wells is to core all doubtful sand intervals to determine the limits of oil saturation. After the total depth is reached an electrical log is made for correlation purposes, sand count, and permeability indications. A blank liner is run to bottom and cemented in place. A water shut-off test is made generally through four shot holes immediately above the first sand that is to be opened for production. The drilling fluid is then displaced from the well with oil and the various zones or sand intervals are gun perforated. The well is then thoroughly washed and placed on production.

To date, in one field, a total of 18 wells have been worked over and deepened in this manner with an increase of approximately 1300 bbl. of net oil a day. Six new wells have been drilled and completed in the same manner for a total of 500 bbl. of net oil a day. Results so far obtained seem to indicate that after the well has been developed satisfactorily, that less trouble is given from running sand or plugging of the liner, resulting in fewer wash and bailing jobs to maintain production; also, with very few exceptions no trouble due to water breaking in has been experienced.

A typical completion by gun perforating for a redrilled well is shown on Fig. 2. The well was completed originally at a depth of 3543 ft., using a slotted liner as shown on the left of Fig. 2. The production prior to deepening was 36 bbl. of net oil and 136 bbl. of water, 80 per cent cut, daily. In September, 1943, the well was deepened 1050 ft. to a depth of 4599 ft. A 6⅝-in. blank liner was cemented in place through the productive section and lapped into the 8⅝-in. casing. The blank liner was gun perforated oposite 16 different productive sand intervals, comprising a total of 610 ft. with 3660, ⅝-in. diameter shots, 6 shots per foot, as shown to the right of Fig. 2. After a month's production the well is now producing 130 bbl. of net oil a day and 5 per cent water.

It will be noted on Fig. 2, the top perforated interval is opposite a sand section open originally to the well and that the source of water prior to deepening has been cased off effectively. It will be noted also that the unperforated blank pipe between the 16 intervals open to production offers complete control over any future water trouble which may develop from any source.

This method of completion has been used successfully in several wells over 7000 ft. in depth with an effective saving of casing, at the same time maintaining the inside diameter of the well equal to or greater than what it would be if larger casing were used and a liner run. The original program in these wells was to complete a well using 7-in. casing with a 4¾-in. slotted liner landed through the producing zone. As a test, in one well, the 7-in casing was set through the producing section and gun perforated after making the required water shut-off test. The productive capacity of the well, as nearly as could be determined from subsurface pressures and other data, was comparable to that of the wells completed in the normal manner.

In the next well and subsequent wells, instead of using 7-in. casing, a full string of 5½-in. casing was run and cemented through the producing section and gun perforated. The tubing size was reduced from 2½ in. to 2 in. and the surface pipe reduced from 13⅜ in. to 10¾ in. The hole size was also reduced from 11-in. to 9⅝ in. The reduction in pipe sizes represented a saving of nearly 45 tons of steel per well. No appreciable difference could be noticed in the productive capacity of the wells completed with 5½ in. casing and those completed with 7-in. casing.

In concluding this discussion it is wished to emphasize again that gun perforating may not be the answer to the problems in each particular field or may not be considered necessary in single zone completions. It is believed, however, the merits of gun perforating for intermediate zonal control in multi-zone fields are recognized generally but that certain objectionable features attributed to this method of well completion have prevented its use as a standard procedure. It is hoped by this discussion that new ideas have been presented on the matter that will lead to other suggestions or possibilities for completing wells in the most efficient and economical manner possible. ★★★

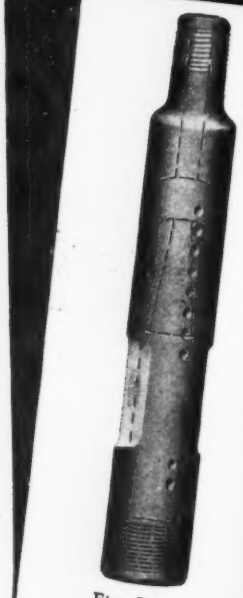

Fig. D312

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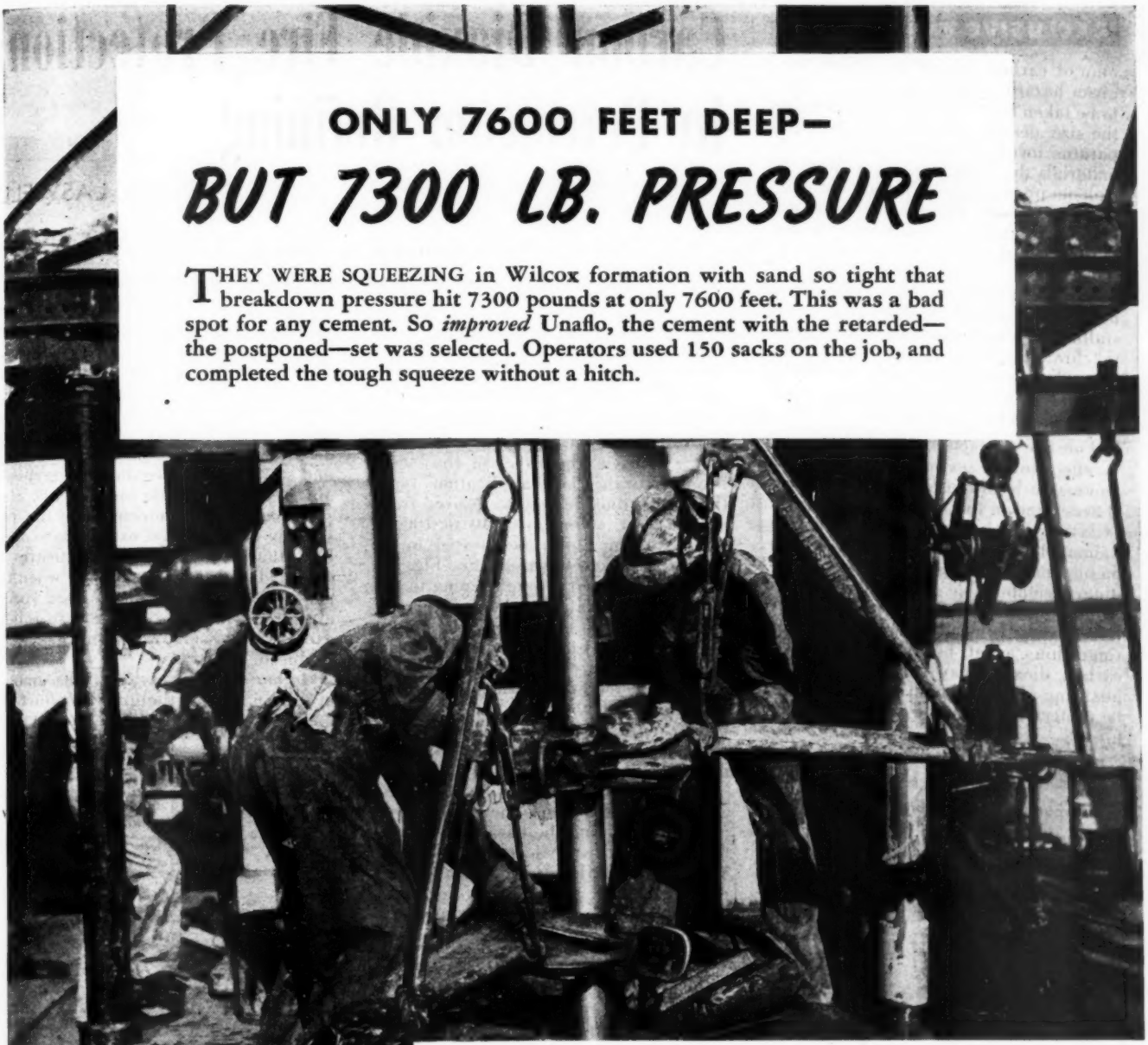

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PE-U-49

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PRODUCT OF UNIVERSAL ATLAS CEMENT COMPANY

Carbon Dioxide Fire Protection In Petroleum Refining

By M. A. LASWELL*

Studies of individual conditions necessary to determine economical and suitable protection

EXCLUSIVE In determining the suitability and economy of carbon dioxide protection for a given hazard, a number of factors have to be taken into consideration, including the size, design, and location of the apparatus involved and the nature of the materials that may be present. With petroleum processing equipment, these factors are subject to wide variation, and individual studies of conditions are usually required before decisions can be reached.

The engineer may have occasion to make such studies in designing or installing new equipment or in improving the fire protection of existing installations. To assist in this work, the fundamental engineering information commonly needed is given herewith.

▼ **For fire protection.** Carbon dioxide is effective for extinguishing fires in flammable liquids (designated as Class B fires) and in live electrical equipment (Class C fires) and also for rendering flammable vapors and gases nonflammable and nonexplosive. For fires in ordinary combustible materials, such as wood, paper, textiles, etc. (Class A fires), water is usually the preferred extinguishing agent, but, in special cases, carbon dioxide may be used for safeguarding articles of high value that must be protected from water as well as from fire.

TABLE 1
Carbon dioxide pressure-temperature relationships

Temperature, °F.	CO_2 pressure, lb. per sq. in abs.*
— 10	260
0	320
10	360
32	460
50	620
70	849
90	1205
110	1725
130	2265
150	2825

*14.7 lb. higher than would be shown by an ordinary pressure gauge.

Carbon dioxide is contained in steel cylinders under a pressure that varies with the temperature. When cylinders are filled to 68 per cent of their water capacity, which is the maximum allowable, pressure-temperature relationships are as given in Table 1.

Cylinders are tested and approved for operation at temperature as low as minus 40° F.

The maximum temperature to which carbon dioxide cylinders should be exposed varies from 130 to 160° F., depending upon the design of the pressure relief and the type of cylinders.

On being released from its container, liquid carbon dioxide discharges in the form of a cloud of gas made visible by condensed atmospheric moisture, with some solid carbon dioxide "snow," the amount depending upon the type of discharge nozzles.

Two types of carbon dioxide protection equipment are employed: Built-in systems, which are used to extinguish fires that cannot be controlled with small units, and portable extinguishers, which are used for general protection against incipient fires and for safeguarding minor hazards.

▼ **Built-in systems.** With a built-in system, which may be either of the "total flooding" or the "local application" type, the carbon dioxide may be derived from one or more cylinders of 10 to 100-lb. capacity, which may be located in or outside the protected area. (See Fig. 1.) The gas is carried through piping to the point of application, where it is discharged through suitable nozzles. More than one hazard may be protected by a single source of carbon dioxide, by the use of selector or directional valves in the piping, which direct the gas to the proper point. Control of the discharge is effected manually or by means of automatic releases.

In total flooding, carbon dioxide is discharged into the atmosphere of the enclosure containing the hazard, thus protecting the entire enclosure against fire. With local application, which is employed for the protection of localized hazards, carbon dioxide is applied around, over, or into the hazard.

▼ **Total flooding.** Total flooding is used in petroleum processing plants for safe-guarding spaces where unusually hazardous processes are carried on or where valuable equipment or material, subject to water damage, is housed. Examples include cracking, filtering, and filling rooms; pump, compressor, and electrical control rooms; pipe trenches, and storage spaces containing irreplaceable records, delicate instruments, etc.

Spaces to be protected may be reasonably well enclosed, or may have openings that are closed automatically or screened with carbon dioxide, when the gas is discharged. Tightly closed spaces are fitted with vents, in order to relieve excessive pressure when the gas is introduced.

Amount of gas required. The amount of carbon dioxide required to reduce the oxygen content of the air below the point where combustion will be supported varies with different materials, and is shown in Table 2 covering certain flammable liquids and gases.

TABLE 2
Fire-extinguishing mixtures of carbon dioxide and air

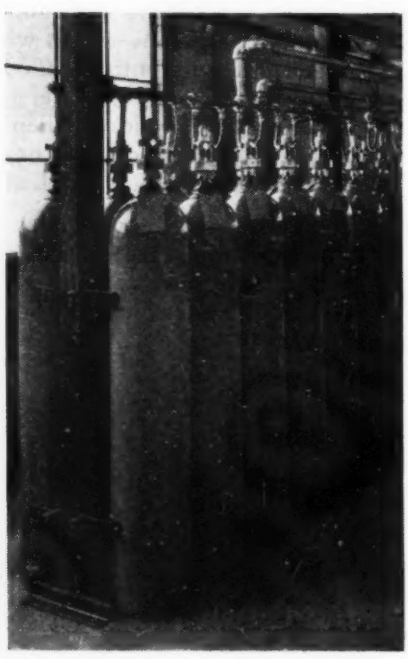
Material	Approx. per cent in mixture	
	CO_2	Oxygen
Acetone	28	15
Ethyl alcohol	28	15
Gasoline	28	15
Kerosine	28	15
Methane	30	14.5
Ether	38	13
Ethene	52	10
Carbon disulphide	62	8
Hydrogen	70	5.9

In general, a carbon dioxide concentration of 45 per cent in the atmosphere will extinguish fires in all flammable liquids, except carbon disulphide, and a concentration of 55 per cent will extinguish fires in Class A materials.

The amount of carbon dioxide, in pounds, required to produce a given concentration in a given space can be calculated accurately enough for practical purposes by assuming that 1 lb. of carbon dioxide occupies a volume of 9 cu. ft. at ordinary temperature and atmospheric pressure. Thus, 2 lb. of gas released in a space of 36 cu. ft. will produce an atmosphere having a 50 per cent concentration of carbon dioxide, assuming no loss of gas and uniform intermixing. The oxygen content of the mixture will be approximately 10 per cent and the nitrogen content approximately 40 per cent.

For flooding spaces containing only

Fig. 1. Built-in carbon dioxide system of 100-lb. cylinders.



*Vice president, C-O-Two Fire Equipment Company.

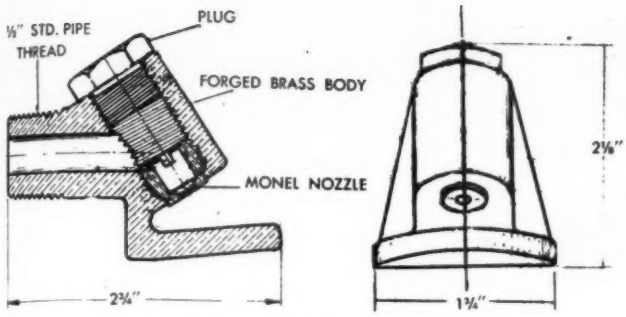


Fig. 2. ***Above*****—Baffle type diffusing nozzle, used in total flooding.**

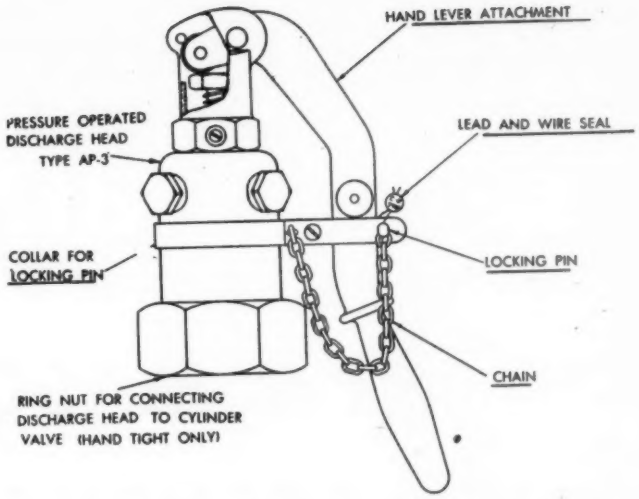

HAND LEVER ATTACHMENT
PRESSURE OPERATED DISCHARGE HEAD TYPE AP-3
LEAD AND WIRE SEAL
COLLAR FOR LOCKING PIN
LOCKING PIN
CHAIN
RING NUT FOR CONNECTING DISCHARGE HEAD TO CYLINDER VALVE (HAND TIGHT ONLY)

Fig. 3. Discharge head of a cylinder discharged by local manual control.

flammable liquid hazards, the amounts of carbon dioxide shown in Table 3 are required by the Underwriters Laboratories.

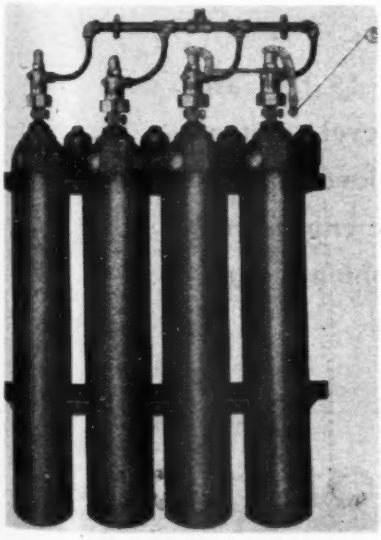
For flooding reasonably tight enclosures containing records or other Class A combustibles that may smolder or glow after ignition, at least 1 lb. of carbon dioxide is required for every 16 cu. ft. of protected space, regardless of size. The gas may be fed in more slowly through smaller orifice nozzles and should be retained for at least half an hour to ensure complete extinguishment.

With rotating electrical equipment, the gas should be fed in continuously to compensate for leakage until the unit is stopped.

Piping. The pipe sizes to be used to carry the full discharge of a battery of cylinders are given in Table 4. Pipe lines serving discharge nozzles decrease in size in proportion to the number and size of the nozzles served.

All piping and fittings must be galvanized seamless steel or brass, as protection from corrosion, and must withstand a bursting pressure of 6000 lb.

Fig. 4. Remote manual control, lever type release. Pulling the cable at a pull box discharges the two control cylinders, causing the other two to discharge automatically.



With cylinder valves having discharge outlets other than ⅜ in., pipe sizes are varied proportionately. Where larger pipe sizes are needed, extra heavy pipe is used in sizes up to and including 6 in.

Nozzles. The nozzles used for total flooding are of the baffle diffusing type, shown in Fig. 2. This type of nozzle ensures the rapid expansion and thorough mixing of the gas without stratification at lower levels.

Controls. To discharge a cylinder used in a carbon dioxide protective system, a piston located in the discharge head of the cylinder is pressed down, which opens the pressure seat or the sealing disk of the cylinder valve and releases the gas.

The following methods of control are commonly used to perform this operation. With multicylinder installations, the control mechanism actuates the discharge heads of only two control cylinders; the remaining cylinders are automatically discharged by the pressure of the gas from the control cylinders.

1. Local manual control is effected by pulling a lever mounted on the discharge head of a control cylinder. (See Fig. 3).

2. Remote manual control permits the operation of the system from one or more cable pull-boxes, located wherever desired. Fig. 4 shows the lever type of release, operated by a cable exposed at the cylinder battery; Fig. 5 shows the discharge head of a control cylinder operated by a cable that is enclosed in conduit throughout its length.

3. Fixed temperature automatic control is governed by one or more fusible links mounted on the ceiling of the protected space. When the air in the space

(Continued on Page 152)

TABLE 3

CO_2 flooding requirements for Class B hazards

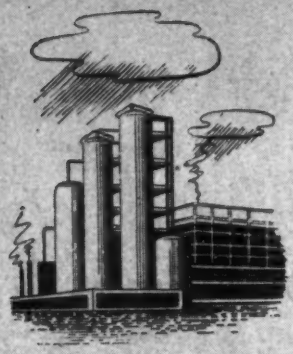
Volume of space, cu. ft. net	Carbon dioxide, lb.	Cu. ft. space per lb. CO_2
100	7.5	13
140	10	14
220	15	15
300	20	15
375	25	15
500	35	15
800	50	16
1,100	70	16
1,600	100	16
2,000	111	18
4,500	250	18
5,000	250	20
10,000	500	20
50,000	2500	20
Above 50,000	....	22

TABLE 4

Pipe sizes for flooding systems

No. of cylinders with ⅜ in. outlets discharging simultaneously	Pipe size, Class B hazards
1 or 2	½ in. std.
3 or 4	¾ in. std.
5 or 6	1 in. ex. heavy
7 to 12	1¼ in. ex. heavy
13 to 16	1½ in. ex. heavy
17 to 27	2 in. ex. heavy
28 to 39	2½ in. ex. heavy
40 to 60	3 in. ex. heavy
	Class A hazards
1 to 5	½ in. std.
6 to 9	¾ in. std.
10 to 13	1 in. ex. heavy
14 to 23	1¼ in. ex. heavy
24 to 32	1½ in. ex. heavy
33 to 53	2 in. ex. heavy
54 to 77	2½ in. ex. heavy
78 to 120	3 in. ex. heavy

Fig. 5. Discharge head of a cylinder for remote manual control by a cable enclosed in conduit throughout its length.



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4. Torque Tube Assembly
Inconel torque tube designed for high temperature, fabricated with all parts made of inconel and welded by the atomic hydrogen electric arc process. Inconel maintains excellent torsion spring properties up to 650° F.

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Special stops provided on all models to protect the torque tube from mechanical over-travel.

6. Case Design
Designed especially for the #12,600 Level Controller. Sturdy ribbed construction to prevent distortion.

7. Left and Right Hand Case Mounting
The case mounting can be reversed in the field without the replacement of any parts.

8. Control Mechanism
New principle. Sensitive to .001" change in level. Complete elimination of pivot bearings. Proportional band adjustment without high multiplication.

9. Unit Assembly
Proportional mechanism, air manifold and pilot are complete sub-assemblies.

10. Bronze Air Manifold
All air passages are bronze or copper, to eliminate the formation of scale or rust beyond the air filter in supply line.

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Large area metal bellows and great air capacity. Unit mounting, eliminating any major air tubing connections.

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The control action is always clearly indicated and the procedure to reverse the action is simple.

14. Proportional Band Scale
Calibrated 1 to 100%.
Scale over 4" long and the graduations are ideally proportioned for easy adjustment.

15. Proportional Band Adjustment
Linear proportional characteristics to close limits in all settings. Adjustment with minimum upset of control point setting.

16. Calibrated Specific Gravity Scale
Adjustable from .5 to 1.2 sp. gr. or from .8 to 2.0 sp. gr.

17. Interface Level Control
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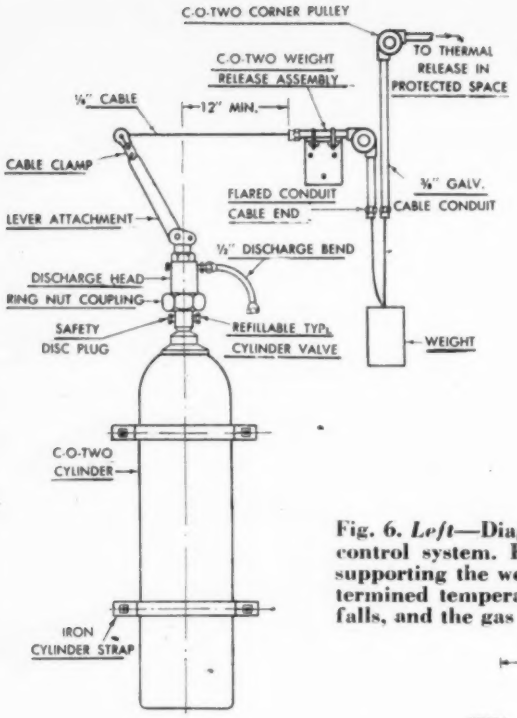


Fig. 6. *Left*—Diagram of a fixed-temperature automatic control system. Fusible link is connected to the cable supporting the weight. When the link fuses, at a predetermined temperature, the cable is released, the weight falls, and the gas is discharged.

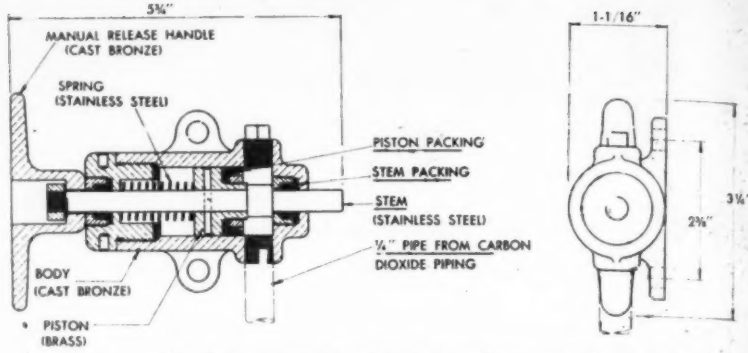


Fig. 7. Pressure trip for closing doors, windows, and ventilating-duct dampers. A chain ending in a ring slipped over the steel stem of the trip is freed when the stem is forced inward by gas pressure, permitting the door or other closure controlled by the trip to be closed by the action of gravity or a suspended weight.

(Continued from Page 149)

reaches a predetermined temperature, a link fuses and releases a cable that supports a weight. Fall of the weight operates the discharge heads of the control cylinders. The mechanism is shown in Fig. 6. Standard links are supplied for operation at 135, 175, 250, or 350°F.

4. Rate-of-rise automatic control used where the temperature may be low or may become high under ordinary operating conditions, functions when the temperature rise is faster than the normal rate. Heat-produced air pressure in rate-of-rise detectors is communicated by copper tubing to the pressure-operated trip of a weight release box, which operates the system.

Automatic accessories. Certain of the following devices, operated by carbon dioxide gas pressure, are usually required in connection with a flooding system:

Pressure trip for closing doors, windows, dampers in ventilating ducts, etc.. (Fig. 7); explosion proof switch for shutting down electric apparatus in the protected space, lighting signal lamps, sounding alarms, etc.; siren alarm to warn workers in the area to leave (Fig. 8); device for delaying gas discharge 30 sec. or more to allow time for evacuation (Fig. 9).

Where there is no one working in the protected area, the warning and time delay devices may be omitted.

A typical flooding installation. Fig. 10 shows the layout of a carbon dioxide flooding system for protecting the oil pump room of an oil refinery.

The dimensions of the pump room are approximately 70 ft. by 28 ft. by 15 ft., giving a volume of 39,000 cu. ft. Carbon dioxide is supplied by a battery of 44 cylinders of 50 lb. each in a screened enclosure in the far corner of

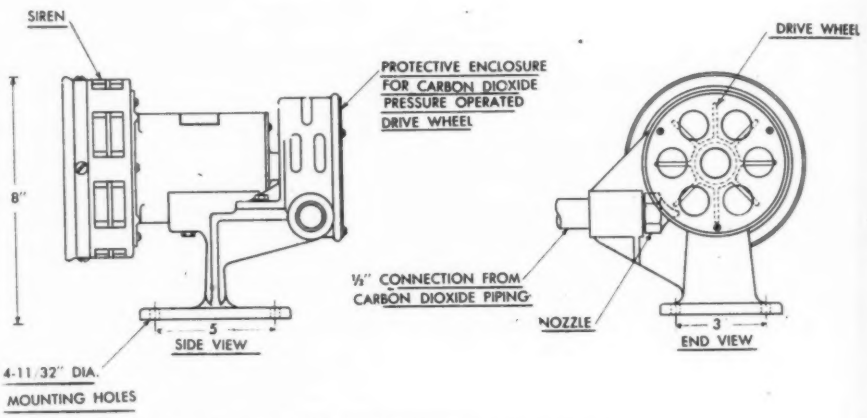
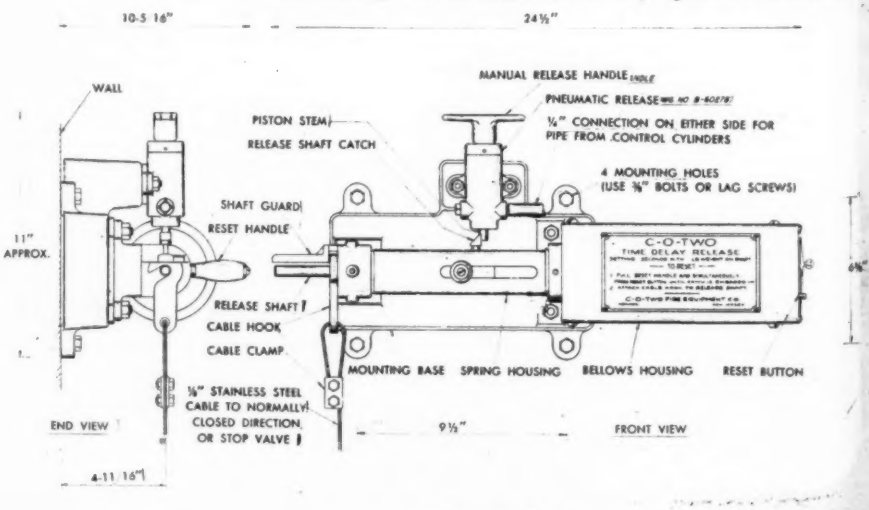


Fig. 8. Siren alarm, operated by carbon-dioxide gas pressure, for warning workers to evacuate space to be flooded by the gas.

Fig. 9. Time-delay release for delaying gas discharge to allow for evacuation of the protected area. The release is located in the piping between the control cylinders and the cylinders operated by gas pressure and is actuated by the pressure of the gas from the control cylinders. The release of the cable, by the withdrawal of the shaft from which it is suspended, permits a stop valve to open. The time setting can be adjusted to any specified interval.



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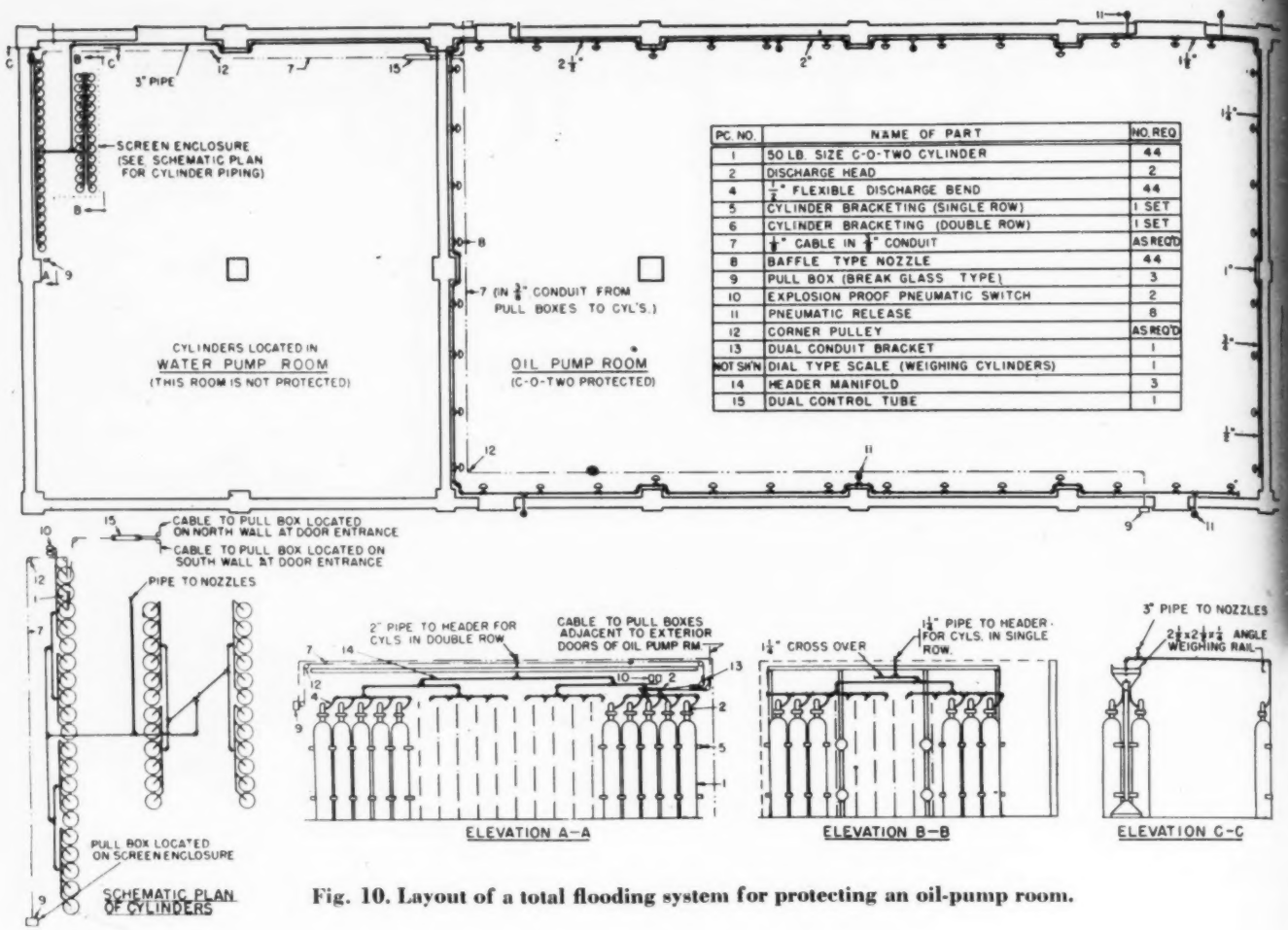

3" PIPE
SCREEN ENCLOSURE (SEE SCHEMATIC PLAN FOR CYLINDER PIPING)
7 (IN 1" CONDUIT FROM PULL BOXES TO CYL'S.)
CYLINDERS LOCATED IN WATER PUMP ROOM (THIS ROOM IS NOT PROTECTED)
OIL PUMP ROOM (C-O-TWO PROTECTED)
CABLE TO PULL BOX LOCATED ON NORTH WALL AT DOOR ENTRANCE
CABLE TO PULL BOX LOCATED ON SOUTH WALL AT DOOR ENTRANCE
PIPE TO NOZZLES
PULL BOX LOCATED ON SCREEN ENCLOSURE
SCHEMATIC PLAN OF CYLINDERS
2" PIPE TO HEADER FOR CYLS. IN DOUBLE ROW
CABLE TO PULL BOXES ADJACENT TO EXTERIOR DOORS OF OIL PUMP RM.
ELEVATION A–A
1½" CROSS OVER
1½" PIPE TO HEADER FOR CYLS. IN SINGLE ROW.
ELEVATION B–B
3" PIPE TO NOZZLES
2½x2½x¼ ANGLE WEIGHING RAIL
ELEVATION C–C

PC. NO.	NAME OF PART	NO. REQ.
1	50 LB. SIZE C-O-TWO CYLINDER	44
2	DISCHARGE HEAD	2
4	1" FLEXIBLE DISCHARGE BEND	44
5	CYLINDER BRACKETING (SINGLE ROW)	1 SET
6	CYLINDER BRACKETING (DOUBLE ROW)	1 SET
7	½" CABLE IN ¾" CONDUIT	AS REQ'D
8	BAFFLE TYPE NOZZLE	44
9	PULL BOX (BREAK GLASS TYPE)	3
10	EXPLOSION PROOF PNEUMATIC SWITCH	2
11	PNEUMATIC RELEASE	8
12	CORNER PULLEY	AS REQ'D
13	DUAL CONDUIT BRACKET	1
NOT SH'N	DIAL TYPE SCALE (WEIGHING CYLINDERS)	1
14	HEADER MANIFOLD	3
15	DUAL CONTROL TUBE	1

Fig. 10. Layout of a total flooding system for protecting an oil-pump room.

the adjacent water pump room. This battery provides 1 lb. of gas for every 18 cu. ft. of protected space, which is a somewhat greater quantity than the Underwriters' requirement of 1 lb. per 20 cu. ft. for large spaces and was considered desirable by the purchaser as extra protection for this particular installation.

A line of 3-in. piping runs from the cylinder battery to the oil pump room, where it feeds into two branches, each of which runs along two sides of the room and discharges through 22 equally spaced nozzles. The piping of the branches starts as a 2½-in. extra heavy and diminishes by steps to ½-in. standard.

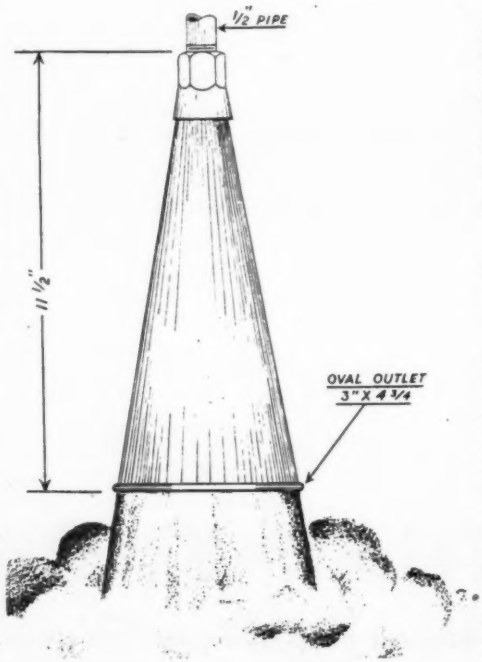
The discharge of the gas is controlled manually from three pull boxes, two being located just outside doors on opposite sides of the pump room, and the third outside the enclosure screening the cylinder battery. The pull cables, of ⅛-in. stainless steel, are enclosed in ⅜-in. conduit and are connected by levers to the discharge heads of two control cylinders.

Each of the three single doors and each leaf of the double door leading into the pump room is closed by a pressure trip when the gas is discharged. Three more trips close ventilating duct dampers.

Two 2-pole explosion-proof pressure-operated switches, mounted within the cylinder battery enclosure, shut down the electrical equipment in the protected space.

The cylinders are arranged in three rows, with space enough between rows to permit easy access for servicing. A length of 2½-in. by 2½-in. by ¼-in. angle iron, mounted above each row, provides support for the spring balance used in weighing the cylinders in place, during periodic weight inspection.

Fig. 11. Horn type nozzle, used in local application systems.



▼ **Local-application systems.** Locally applied carbon dioxide is used for protecting tanks and pits containing flammable liquids, drain boards, experimental equipment and other localized hazards.

Open flammable liquid containers of any length and depth can be protected by this method, provided the open top is limited to 12 ft. in width. Containers with wider openings can be adapted for protection by reducing the width of the openings to 12 ft. or less by means of covers that are either solidly installed or are automatically closed when the gas is released.

At least 1 lb. of carbon dioxide for each 0.6 sq. ft. of liquid surface must be provided for protecting petroleum products in open containers.

The nozzles used are of the horn type, shown in Fig. 11, or the baffle horn type, shown in Fig. 12. They are located over or around the opening, and separate the hazard from the surrounding air by a cloud or screen of carbon dioxide. Nozzles must not be placed so close to liquids as to cause splashing.

The carbon dioxide supply cylinders, piping, and controls for local application are the same as for total flooding.

Enclosed containers. Carbon dioxide may be introduced into the vapor spaces of enclosed tanks and other equipment

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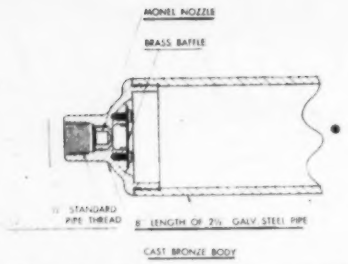

Fig. 12. Baffle horn type nozzle, used in local application systems.

containing flammable vapors in order to extinguish fires in the vapors or render them nonflammable and nonexplosive.

To prevent fire or explosion in a vapor space, the appropriate concentration of carbon dioxide, as given in Table 2, must be maintained in the space and also in the air entering the space.

By using higher concentrations of carbon dioxide, flammable gases can be rendered nonflammable under all conditions of air dilution. The amount of carbon dioxide needed for this purpose in the case of certain gases is given in Table 5, compiled by the U. S. Bureau of Mines:

TABLE 5
Volumes of carbon dioxide to render gases nonflammable

Flammable gas	Vol. CO_2 to 1 vol. gas
Methane	3.3
Ethane	7.3
Propane	7.9
Butane	9.3
Hexane	12.2
Butadiene	14.0
Ethene	12.0
Propene	9.0
Cyclopropane	8.0
Hydrogen	10.2

Hose units. Certain hazards, not serious enough to warrant the installation of a built-in system, but requiring larger protective equipment than hand or wheeled portables, can be adequately protected by hose units, which consist of one or more carbon dioxide cylinders, mounted near the hazard and equipped with a sufficient length of hose, on a rack or reel, carrying a discharge horn and a manually operated control valve. In use, the discharge of gas is controlled and directed by an operator.

Fig. 13. Carbon dioxide wheeled extinguisher of 50-lb. capacity.

TABLE 6
Hand extinguishers

CO_2 capacity, lb.	Discharge time, sec.
2	13
4	18
7½	15
10	28
15	24
20	25

▼ **Portable extinguishers.** The characteristics of the various sizes of carbon dioxide hand extinguishers are given in Table 6.

The size most commonly used in petroleum processing plants is the 15-lb. unit.

For general fire protection, a 15-lb. extinguisher should be available within easy travel distance from any point within the protected area. Additional extinguishers should be installed for the protection of extra hazardous processes.

Wheeled types are supplied in 50, 75, and 100-lb. sizes. (Fig. 13.)

Trailer types for attachment to automobiles are used in refineries. A typical model is equipped with ten 50-lb. carbon dioxide cylinders and 150 ft. of hose, with a hose reel and a large discharge horn.

▼ **Maintenance requirements.** ***Routine inspection.*** Carbon dioxide protective equipment should be inspected at regular intervals to make sure that everything is in good condition and that the equipment is in its proper place and is easily accessible.

Once a month, and more often in war time, each portable should be checked for the presence of a wire-and-lead seal (on the valve), which must be broken to operate the extinguisher. If the seal wire or the tag bearing the last servicing date is missing, or if the cylinder has not been weighed within a year, the extinguisher should be serviced at once.

This work can be performed by regular plant help.

Annual servicing. This work involves the inspection of all parts, including piping and nozzles, and the weighing of each carbon dioxide cylinder.

Recharging. Carbon dioxide cylinders are recharged by service agencies and carbon dioxide manufacturing plants located in all principal cities.

As carbon dioxide does not deteriorate, recharging is necessary only after cylinders have been discharged.

★ ★ ★

Oil subsidy is expression of "mature" economy

"Do you want the difference in a nutshell, between the two great systems of economy that have been contending in this country for the last decade? If you do, look to the petroleum industry.

"This industry has been a battle-ground between the two philosophies. Gradually the struggle has been intensified. It now has come to a head with something which tells the whole story succinctly.

"That something is the new crude oil subsidy for stripper wells. Has there ever been anything more revealing? The writer thinks not.

"This subsidy plainly shows the workings of the theory of centralized, paternalistic largess, dedicated to the attempt to guarantee security. It shows this not only by what it is, but also by what it is not.

"Do you doubt it? Then consider that there is not the slightest thing about this subsidy which even faintly stimulates activity looking toward exploration or development of new sources of supply.

"There is nothing in it which follows the great tradition on which this country was founded and grew strong—the stimulation of enterprise by the promise of adequate return.

"The new crude oil subsidy is a tell-tale. It clearly expresses one side of the argument—the side of the Washington administration.

"It says that we must hold on to what we have—never mind about trying to improve our position.

"It says that we should devote our energy to digging in, to maintaining the negative side, to giving our economy the aspects of an old, or at least a mature way of life.

"It is true that stripper wells deserve special consideration. They should have had it long ago. They would have had, in all probability, except for Washington's heavy regulatory hand.

"But what about consideration for activity devoted to discovery and making available the needed supplies from new sources?

"Vigor and virility in this industry have had a terrific workout in recent years. It may not be appropriate to say they have been stultified. It may be they have had to work so hard to stay alive on any basis against odds that they have become inherently stronger.

"The fight has not ended. There is reason to suppose that eventually the issues will have to be resolved in some more fundamental fashion than by the reluctant granting of something like a gift, something to make the recipients look to Washington, something which is a hidden increase in price, handled so as to prevent its showing up in the commodity price records."

Kieth Fanshier in Chicago Journal of Commerce.

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By RECTOR

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Horizontal Drilling Is Tried In Partially Depleted Fields

By WALLACE A. SAWDON

Method serves as means of tapping less thoroughly drained areas between wells

Editor's Note: Two experimental jobs performed with the equipment herein briefly described have indicated the possibilities of drilling horizontally from old wells. A complete test operation is about to be started and upon its completion, with equipment installed for production, a more detailed discussion of the project will be given.

EXCLUSIVE A MEANS of tapping less thoroughly drained areas lying between wells in partially, or almost completely, depleted fields has recently been developed, and the drilling procedure using equipment designed for the purpose has been tried out experimentally in two wells in the Midway-Sunset area of California. The method consists essentially of cutting a window, or otherwise providing an opening, through the liner at a predetermined depth in the producing zone of a well and through this opening drilling a horizontal hole in a specified direction to a desired distance from the bore of the vertical well employed for the purpose. Using the one well, three or four horizontal holes may be drilled and these holes may be at different levels. (See Fig. 1.)

The method of horizontal drilling was devised and the equipment designed by J. A. Zublin of Universal Engineering Company, Ltd., Los Angeles. The outstanding features of the equipment are a turbo bit and flexible drill pipe. The bit is rotated by the drilling fluid, which is circulated by the mud pumps, the mud being maintained at a suitable viscosity for operation of the bit. The drill string is, of course, not rotated.

The lower part of the drill string consists of the necessary number of joints of flexible drill pipe to carry the hole horizontally from the bore of the vertical well to the location in the sand to which the horizontal hole is to be drilled. The bottom flexible joint to which the bit is attached is made from a curved section of drill pipe, which causes the hole to start off in an arc as the bit begins cutting after it passes through the window in the liner. The other flexible joints are straight. The upper portion of the drill string is made of conventional drill pipe.

The flexible joints are made from 4½-in. external flush joint drill pipe as shown in Figs. 2 and 3. A spiral slot is cut through the wall of each joint of pipe throughout that length of the joint between points approximately 15 in. from each end. The slotted body of the joint is then lined inside with rubber and this rubber lining is made fluid tight at each end to prevent leakage of the power-circulating fluid. The spiral slot provides adequate flexibility for the pipe to change from a vertical to a horizontal position as it passes from the vertical well bore into the horizontal hole.

The curved joint is formed into an arc with a 20-ft. radius before being slotted. Arcs of greater and less radii may also be used. When unflexed, this joint tends to return to its curved form. Before being run into the well a mandrel is placed as a core through the curved joint to keep it approximately straight until it reaches position at the window through which it is to pass. The mandrel is equipped for recovery in a manner similar to wire line coring equipment and is removed when horizontal drilling operations are to begin.

By orienting the drill string into the well, the bit attached to the end of the curved joint of flexible pipe will be opposite the window. When the mandrel is removed from this joint, the pipe will try to return to its curved shape and thus start the bit out through the window. Successive straight joints of flexible pipe will follow through the window along the curved course made by the curved joint and will return to straightness in a horizontal position as the horizontal hole is drilled.

The first experimental run was made in a well drilled to below 1500 ft. and the second in a well below 1100 ft. In both wells the horizontal hole was started near the bottom of the producing zone.

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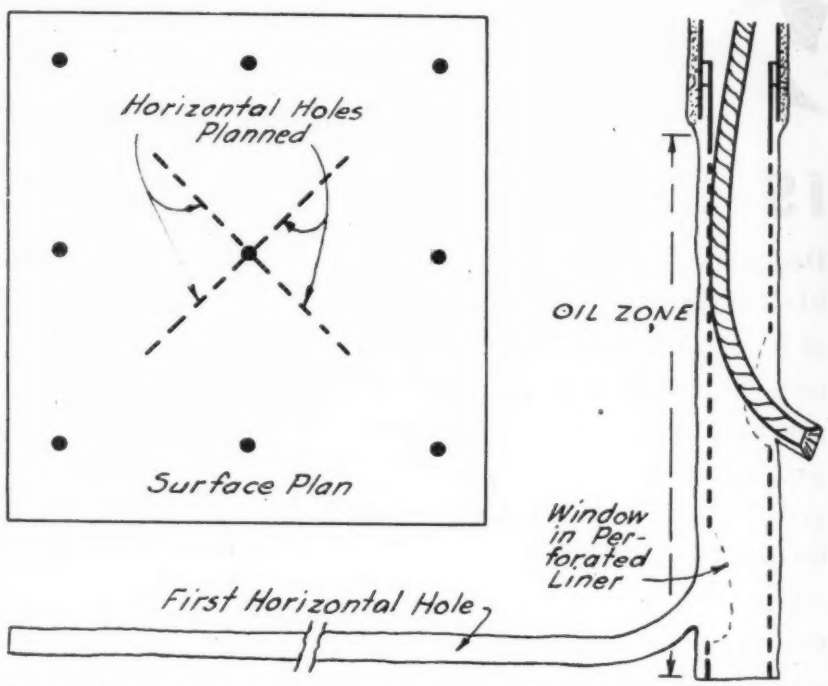
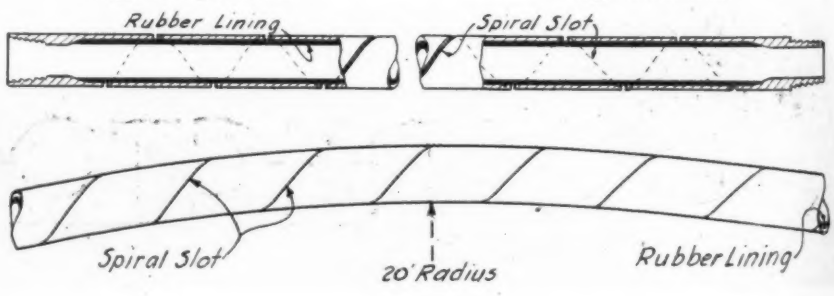


Fig. 1. The general application of horizontal drilling is here indicated. There may be two, three or four horizontal bores planned to go in predetermined directions. In the subsurface sketch, one horizontal hole has been completed and a second is just being started. Drawings are merely illustrative and not to scale.

Fig. 2. Top sketch. **Fig. 3. Bottom.**



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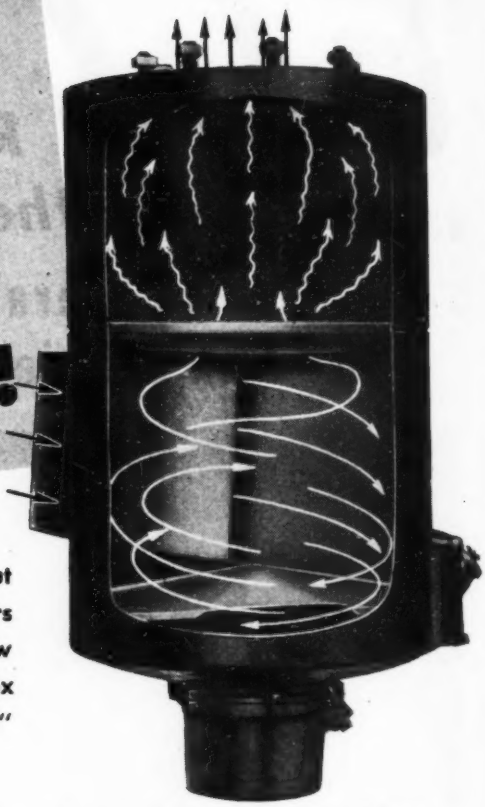

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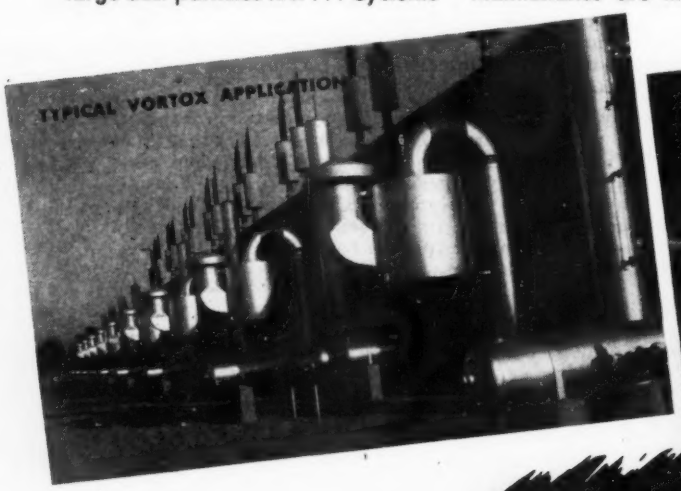

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CALIFORNIA'S FIRST CYCLING PLANT ON STREAM

By WALLACE A. SAWDON

Compact and automatic, new unit-operated plant has centralized control for each well

EXCLUSIVE The first cycling plant in California went on stream on June 10, 1944, and is expected to be running at full capacity of 50,000,000 cu. ft. of overhead flash vapors before the end of August. This plant, situated in the Paloma field, 22 miles southwest of Bakersfield, California, takes production from a condensate zone in the field, and, after recovering the condensate formed by retrograde condensation and the lighter hydrocarbons from the wet gas by absorption and distillation, returns the residue gas to the same zone to maintain reservoir pressure sufficiently high to prevent excessive liquefaction of condensate within the formation.[1]

The Paloma cycling plant, while not the largest in the United States, incorporates the most advanced designs and has the feature of a centralized control at the plant for each individual well, both production and input. It is extremely compact and has been made as automatic as possible to increase safety and efficiency in operation.

The plant was built and is being operated, and the field is being developed under a unit plan for cycling the Paloma sand section, which occurs at a depth of approximately 10,000 ft. and consists of approximately 180 ft. of net sand thickness extending through some 500 ft. of zone. At present there are six companies participating in the Paloma unit. These are: Western Gulf Oil Company, The Texas Company, The Ohio Oil Company, Union Oil Company, General Petroleum Corporation, and the Barnsdall Oil Company. The actual field and plant operations are handled by the Western Gulf Oil Company under the direction of the Paloma Operators' Committee, consisting of members of the six interested companies, of which R. P. Huggins, general manager of the Western Gulf, is chairman. R. M. Dillard is plant superintendent.

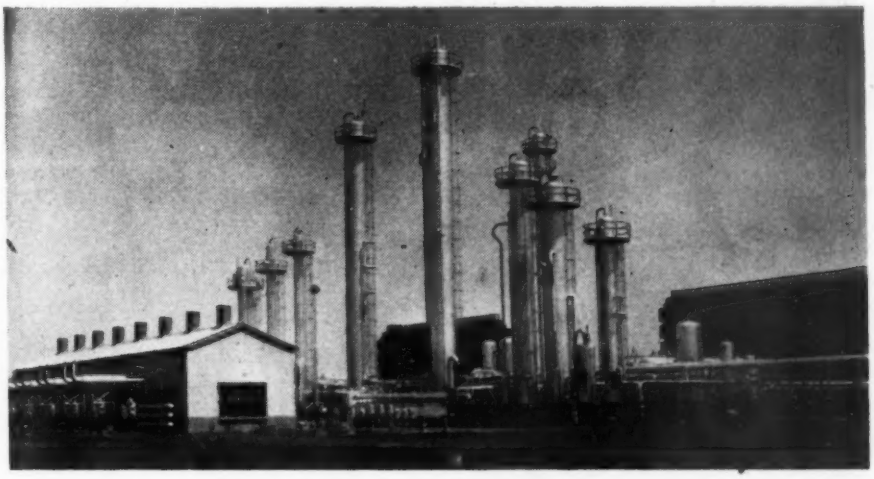
The unitized area at present has about 2800 acres and may be expanded to include additional acreage as productive wells are drilled outside the unit boundaries by the individual companies having outside acreage. A black oil band, which exists on the northeast side of the field, also comes under the unit operations. The Paloma Operators' Agreement does not cover the development of any sand body that may be productive within the field other than the Paloma sand section. Condensate production has been found in the Symons sand on the southeast end of the Paloma field.

Each condensate well is connected directly to the plant through 3½-in. O.D. XX pipe good for 5000 lb. per sq. in. working pressure. The gas lines to the injection wells are of the same size and kind. Both the production and injection lines are laid above ground because of corrosive soil conditions and are insulated for the entire distance from well to plant to insure uniform temperature conditions of the flow to the plant, and to prevent formation of hydrates in the gas injection lines.

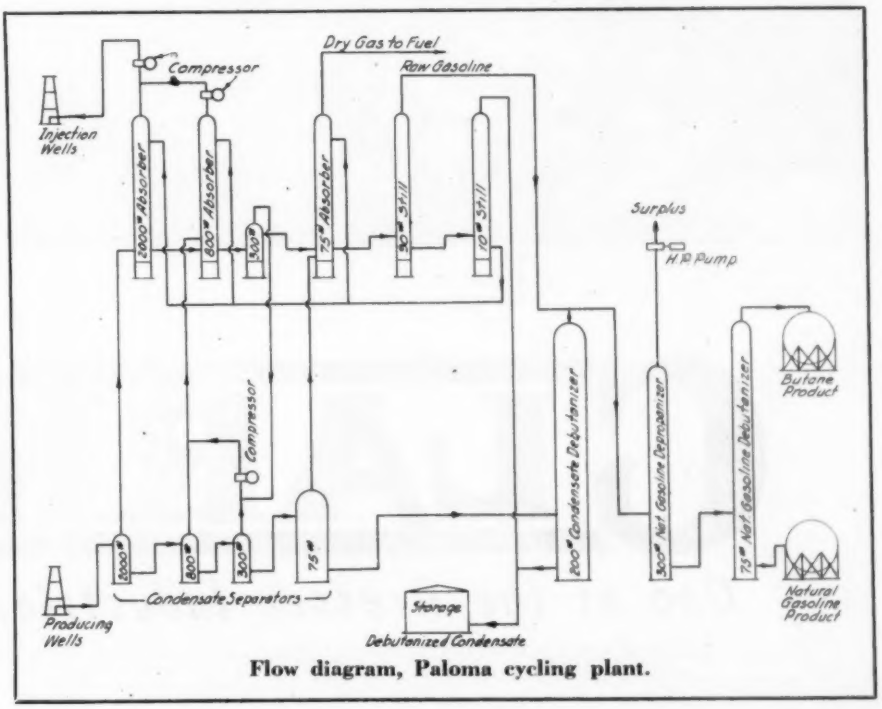
The flow from each well is controlled through the header system or central control station at the plant as is the injected gas to each well. The lines to and from the individual wells are equipped with orifice meters at the plant header for measuring the production from or the injected gas to the respective wells. The producing pressures of the wells vary between 2200 and 3000 lb. per sq. in., which is reduced to 2000 lb. per sq. in. at the plant. The wet gas is cooled to 100° F. temperature before processing. The dry residue gas is compressed to 4300 lb. per sq. in. for injecting into the wells. The temperature of this gas at the plant is approximately 190° F.

The central control station or plant header provides for operating each well independently without going into the field. Flow to or from the plant can be regulated or shut off entirely and by means of a test separator any well can be tested at any time. This facilitates in

(Continued on Page 166)



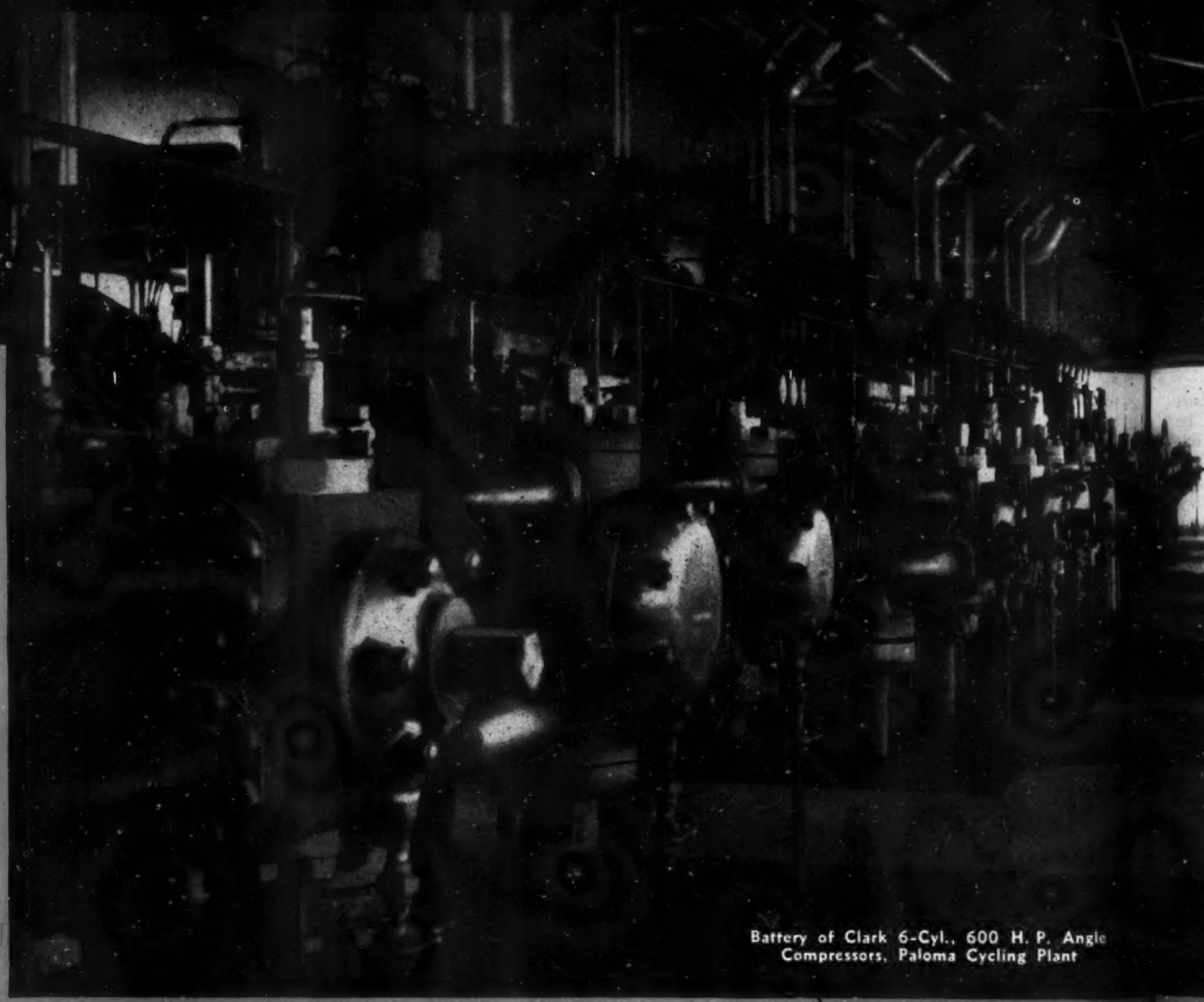
General view of the Paloma cycling plant.



Flow diagram, Paloma cycling plant.

[1]No attempt will here be made to discuss the principles of production of gas-condensate fields. These have been covered in "A Special Section on Recycling" starting on page 51 of the February, 1941, issue of *The Petroleum Engineer*.

3,600 H.P. of CLARK



Battery of Clark 6-Cyl., 600 H. P. Angle Compressors, Paloma Cycling Plant

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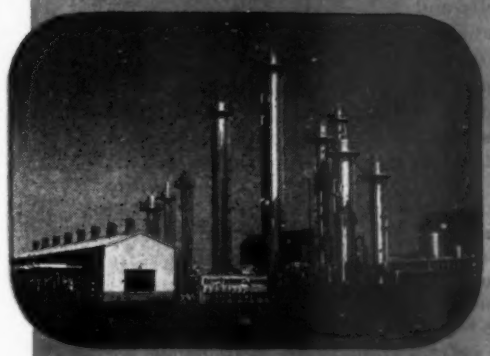
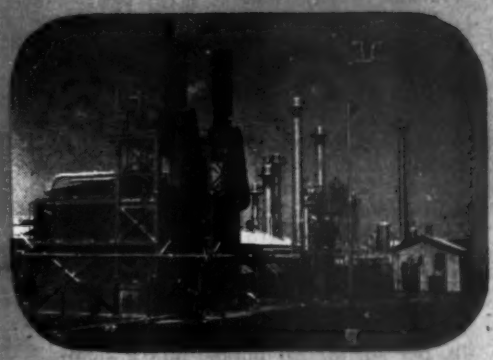
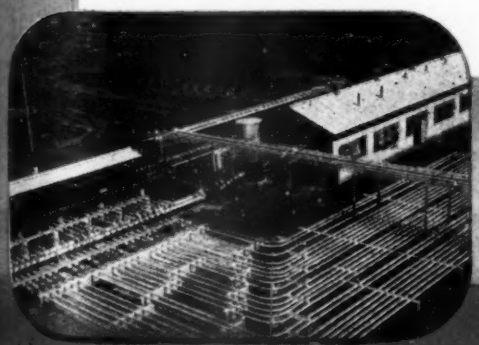
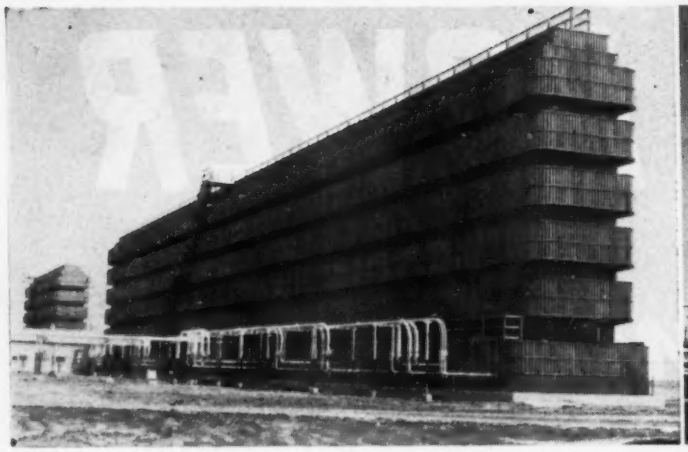
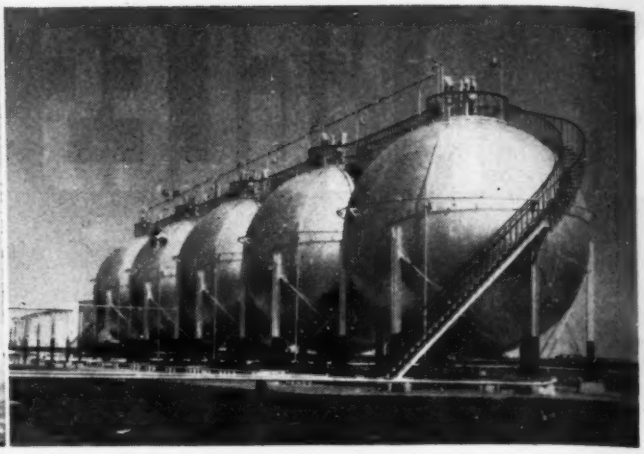










Left—In the foreground is the process cooling tower. Beyond is a smaller tower for cooling engine water. Right—Butane and natural gas are stored in these five Hortonspheres.

(Continued from Page 163)

checking individual well flow conditions (condensate and gas) into the plant as to both volume and character, and provides a means of back-flowing injection wells in case of sand plugging. At the time of writing, there are 3 producing wells and 4 injection wells serving the plant.

▼ **Cycling-condensate-absorption plant.** The Paloma field lies adjacent to the present Buena Vista Lake and the plant is situated on a higher portion of the old lake bed separated from the lower part by a dike. There is always a possibility of water rising in the lower lake bed high enough to flood the entire area so a levee has been built around the entire plant to make sure that it is never flooded. The plant having been built on the old lake bed, all foundations had to be carried from 10 to 15 ft. below the ground surface before suitable bearing formation was found. All foundations are of concrete and the buildings of steel and Transite construction.

The products being recovered at the present time are a debutanized condensate, natural gasoline, and butanes. Facilities may be readily added for processing propane when the demand arises. An impure liquid propane product now formed is injected into the formation. The greater part of the debutanized condensate and the greater part of the natural gasoline are transported by The Texas Company, purchaser, through a 6-in. pipe line connecting to the General Petroleum Corporation's Emidio Station, under a pressure of approximately 450 lb. per sq. in. All butane and a small amount of gasoline and condensate are shipped by truck, so a loading rack has been constructed for loading the trucks.

The condensate-gas production from the field first passes through a 2000-lb. per sq. in. separator. The condensate is then flashed at pressure stages of 800, 500, and 75 lb. per sq. in. The condensate recovered under pressure of 75 lb. per sq. in. is pumped to a debutanizer column operating at a pressure of 200 lb. per sq. in. Here the butanes and lighter fractions are taken off for further fractionation and the bottoms, consisting of debutanized or stabilized condensate, are piped to storage.

The gas from the 2000-lb. per sq. in. separator flows to a 2000-lb. per sq. in. absorber where it is stripped of natural gasoline and butanes under pressure of 2000 lb. per sq. in. The residue gas from this absorber goes directly to the compressors where it is boosted to 4300 lb. per sq. in. for injection into the formation.

The gas from the 800-lb. per sq. in. separator goes to an 800-lb. per sq. in. absorber for stripping at that pressure. The residue gas from this absorber is compressed to 2000 lb. per sq. in. and commingled with the dry gas from the 2000-lb. per sq. in. absorber for compressing to the injection pressure of 4300 lb. per sq. in.

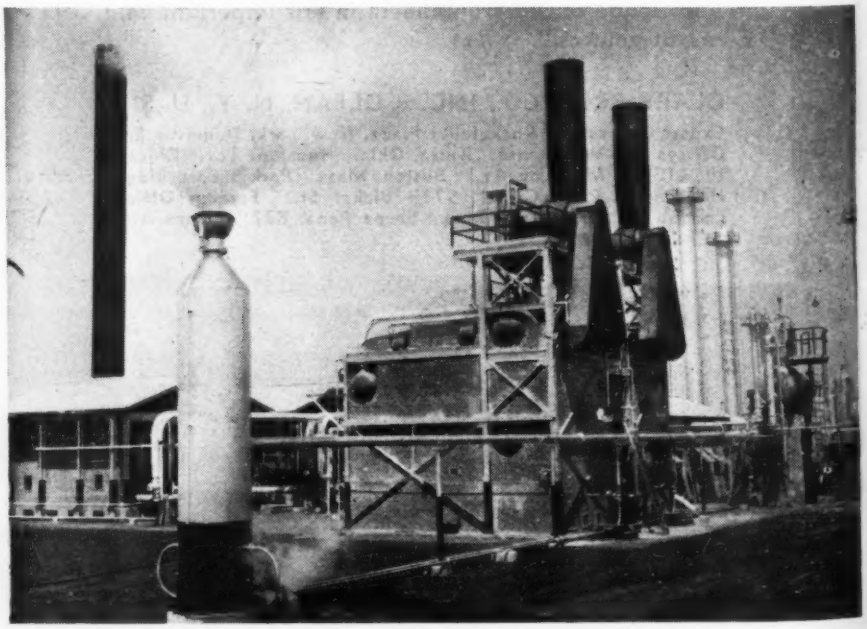
The enriched absorption oil from the two high pressure absorbers is reduced in pressure and piped to a vent tank operating at 300 lb. per sq. in. The released vapors from this tank are combined with the gas from the 300-lb. per sq. in. condensate separator. This commingled wet gas is compressed to 800 lb. per sq. in. for circulation through the 800-lb. per sq. in. absorber.

The gas from the 75-lb. per sq. in. separator goes to a 75-lb. per sq. in. absorber and the residue gas from this absorber furnishes the fuel for plant operation.

The enriched oil from the absorbers is distilled in a still at 90 lb. per sq. in. The raw gasoline overhead cut from this still is combined with the overhead vapors from the 200-lb. per sq. in. condensate debutanizer column and sent to a depropanizer operating at 300 lb. per sq. in. The bottoms from the 90-lb. per sq. in. still go to a 10-lb. per sq. in. still where lower fractions are removed from the lean absorption oil and sent to the condensate storage. The lean absorption oil is then recirculated through the absorbers. Equipment is available for making absorption oil at the plant if the raw material from the field proves suitable.

The overhead from the depropanizer is an impure propane product, which, because of lack of demand, is not taken off

In the foreground are the two 540 hp. 3-drum water-tube boilers. Behind these to the left can be seen the two 15,000,000 B.t.u. furnaces.



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ror further fractionation at the present time. The bottoms are fed to another debutanizer column at 75 lb. per sq. in. The overhead from this column is a butane product including isobutane. The bottoms are natural gasoline.

▼ **Compressor station.** In the compressor house are 6 "angle type," 6-cylinder compressors with a capacity of 600 hp. each, or a total of 3600 hp. These are used for recompression of gases at lb. per sq. in. of from 75 to 300; 300 to 800; 800 to 2000, and from 2000 to 4300. The 4 stages of compression are split over the entire group of machines so that if any one machine goes down the services are more or less reduced proportionately.

Five of these engines have two 4300-lb. per sq. in. discharge cylinders; the other engine has three 4300-lb. per sq. in. discharge cylinders, making a total of 13 cylinders of this capacity. Each of the 6 units has one 800 to 2000-lb. per sq. in. discharge cylinder. Two of the units have one each of the 300 to 800-lb. per sq. in. discharge cylinders and 2 others have one each of 75 to 300-lb. per sq. in. discharge cylinders. One unit has a common spare for use between the 2 low pressure services. All compressor discharge cylinders are equipped with pop valves and rupture disks.

▼ **Other plant equipment.** Two cooling towers serve the plant. One is used for process cooling and the other for cooling the engine water, which is circulated in a closed system. The process cooling power circulating pumps, the jacket water circulating pumps, and the jacket water cooling tower pumps are all identical units driven by 100-hp. gas engines. These units have a capacity of 2500 gal. per min. each. Three pumps on the process tower, two jacket water tower pumps, and two jacket water circulating pumps thus have a total capacity of 17,500 gal. per min. These pumps are in two pump houses and there is one spare in each house. Three 2000 lb. per sq. in. lean oil pumps are also driven by 100-hp. gas engines, making a total of twelve 100-hp. gas engines on these pump services.

Nearly all the reciprocating pumps used for process work discharge at 110-lb. per sq. in. back pressure on exhaust steam. Turbines exhaust into a 5-lb. steam system, which goes back to boiler preheaters.

Steam is generated by two 540-hp. 3-drum water-tube boilers. There are two 15,000,000-B.t.u. furnaces, one for the fat oil service and the other for reboiler service. There is also one 500,000-B.t.u. furnace on reclaimer service.

All products are controlled to specifications with samples of liquid being taken at any point in the process. The laboratory is completely equipped and includes a Podbielniak hyd-robot, low temperature, fractional distillation apparatus, a charcoal unit, and all other usual laboratory equipment generally employed in a natural gasoline plant.

The main storage facilities consist of five 2500-bbl. Hortonspheres and three 10,000-bbl. standard A.P.I. bolted tanks. Three of the Hortonspheres are 100-lb. per sq. in. working pressure receptacles used for storage of butane; the other two are 50-lb. per sq. in. working pressure receptacles used for natural gasoline storage. The stabilized condensate is stored at atmospheric pressure in the three tanks.

▼ **Safety features.** Automatic controls and other features add to the safety and efficiency of the Paloma cycling plant. Liquid floats on the suction lines from the four scrubbers operate an alarm system. When the liquid rises too high in any one separator, a red light shows on a light panel and an audible alarm is sounded. If the condition is not rectified the magneto of the machine that is on that particular service is grounded and the compressor stopped. At one point in the plant all compressor units can be manually grounded.

At the central flow control station a controlled valve on the production manifold maintains a down-stream pressure of 2000 lb. per sq. in. If this pressure drops to approximately 1600 lb. per sq. in., the valve automatically shuts off all gas into the plant. There are two points in the plant from which a solenoid can be manually operated to shut this valve.

All lighting is controlled from a central switch station but individual switches are provided at local points. The entire plant is equipped with an inter-communicating telephone system with nine stations located at most convenient points.

All piping is above ground except the fire protection mains and waste lines. A complete loop system of underground water mains serves the plant for protection against fire. This is provided with block valves to route water to any point in the plant if the system is damaged at any place. Permanent fog nozzles have been installed on each Hortonsphere, one band around the equator and another around the top.

Hose carts with fog nozzles and applicators are located around the grounds with connections to the fire protection water mains at necessary points. Two foam generators also serve for protection against fire. One is situated at the storage end of the plant and the other at the opposite end. The one at the storage end has connections to foam chambers on each of the 10,000-bbl. tanks. Also distributed around the grounds are portable foam generators and hand size foam and CO_2 containers.

▼ **Black oil production.** Due to the slower development of the black oil band and the lack of knowledge on the extent of this area up to the present time, no facilities have been installed for handling black oil production. Plans are now being formulated, however, for producing black oil and processing the accompanying wet gas produced in the plant.

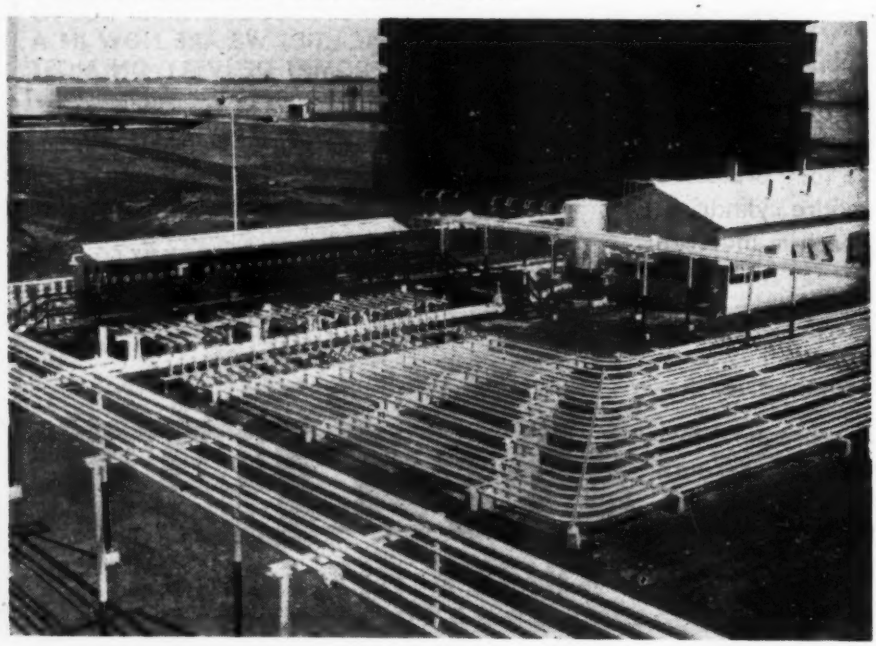
★ ★ ★

No forms for subsidy

Producers will have no additional forms to fill out as a result of premium prices to be paid for crude oil produced in small-yield fields, the OPA has emphasized. Purchasers, however, will be required to fill out a form certifying that the premium was paid to the producer. Purchasers who do not make such a certification will not be eligible for reimbursement.

The increase, ranging from 20 to 75 cents a barrel, was approved July 6 by the Office of Economic Stabilization, to encourage production in low-yield fields. The $50,000,000 annual cost of the subsidy plan will be defrayed by the Reconstruction Finance Corporation through the Defense Plant Corporation, which will pay purchasers for premium prices paid to producers.

Control of flow from all producing wells and to all injection wells is carried on at this station. Lines to and from every well serving the plant are here shown. Under cover are meters for measuring flow to and from each individual well. Behind the meter house is the manifold system.



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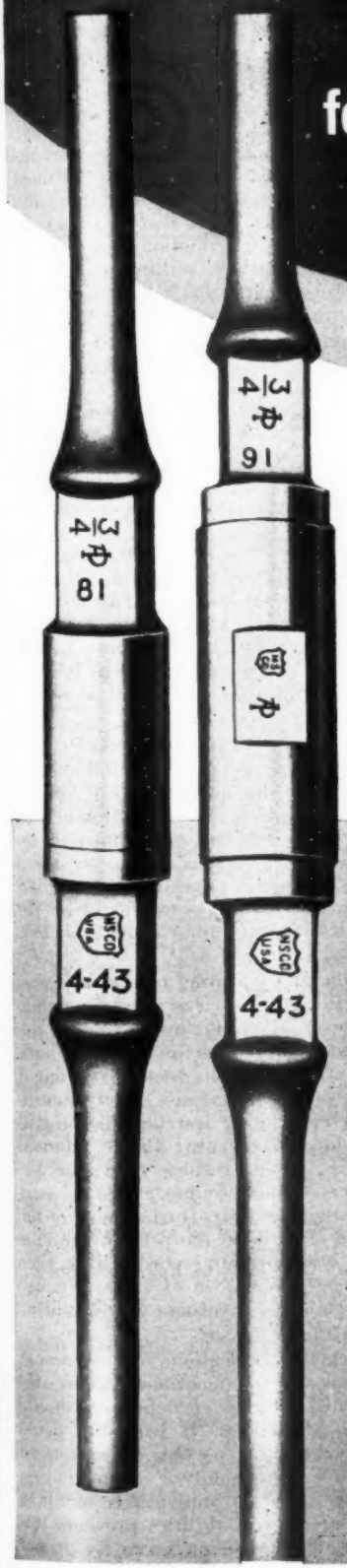

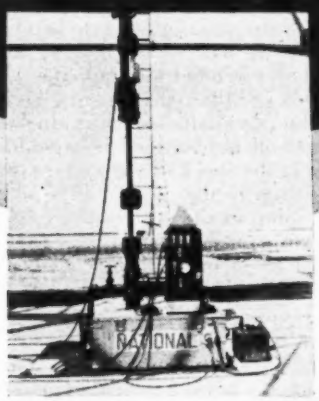

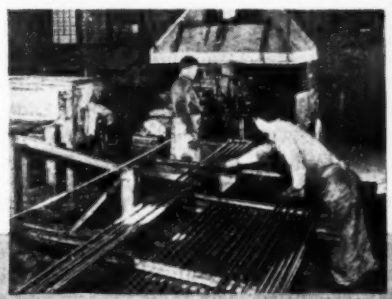

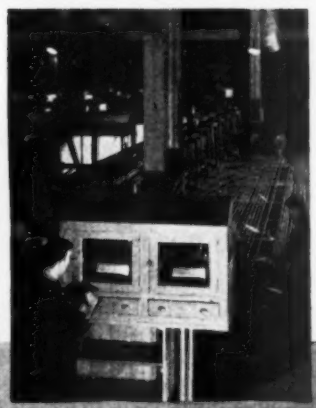

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Symptoms of Pipe Break-offs On Mechanical Rotary Rigs

By HARRY F. SIMONS*

Indications are difficult to recognize except when a decrease in weight of drill pipe is observed

EXCLUSIVE That the seriousness of most fishing jobs can be reduced and the occurrence of this hazard of rotary drilling curtailed is the contention of many. The avoidance of a break in the drill pipe depends on the drilling crew's recognition of the symptoms that precede the break-off, commonly called twist-off, and serious fishing troubles can be avoided if the break-off is recognized as such as soon as it takes place.

The recovery of a fish due to a simple break-off that leaves a clean top is a routine matter requiring only one or two trips with the overshot. The worst complication is a cavity in the hole, which makes it difficult to find the top of the fish, but this can be overcome through the use of a dog-leg joint, knuckle joint, and wall hook, singly or in combination with each other.

If the fish has been run on due to the break-off not being recognized, a very difficult fishing job requiring weeks to clean up can be created. The simplest obstacle created is the belling out of the top of the fish so that at least several mills have to be run before the overshot will pass over it. Worse yet, the top of the fish may be slivered or spiraled around itself so that a week or more may be required to get the fish in condition where it can be picked up with an overshot. In many instances when this situation exists the simplest remedy is to wash over and cut out a joint or two so that a clean top on the fish is presented.

Generally a break in the drill pipe is preceded by washing out at the point of break. Once erosion by the drilling fluid reaches the point where it has cut through the wall of the pipe it accelerates and the opening is extended more or less rapidly depending on the amount of abrasive material in the mud and the pump pressure. Generally the opening progresses circumferentially around the pipe. The length of the wash-out that must develop before a break takes place depends on the age and condition of the pipe, the amount of flexing of the drill pipe at that point, and the torque on the drill stem. At times an opening less than 1 in. long and ¼ in. wide may be all that is needed to develop a break, whereas on the other hand an opening of the same width extending almost half-way around the circumference of the pipe may be present and the break still not occur.

A drill pipe break-off and the washed-out condition that precedes it are much more difficult to recognize on a mechanical rig than on a steam-driven one. On the latter type rig only ordinary caution and observation are required to catch a wash-out before a break develops and generally the actual parting of the drill pipe is known immediately. The symptoms of a pump-out and a break-off are the same on all type rigs except they are masked on a mechanical rig to the point where they are quite often missed.

The easily recognized symptoms of a leak in the pipe due to washing out on a steam rig are: (1) A loss in pump pressure, (2) an acceleration in the number of strokes per minute of the pump, and (3) a decrease in the rate of penetration due to part of the drilling fluid being short-circuited through the leak in the pipe and the consequent reduction in the fluid available to clean the bit. The break-off is identified by a sudden increase in the speed of the rotary table, a sharp drop in the pump pressure, an upward jump in the strokes per minute on the pump and a decrease in the weight of the drill string as shown by the weight indicator.

On an engine-driven rig the pumped-out place in the pipe can develop without any decrease in the pump pressure as the pump is beyond its maximum output. A plain end joint of pipe on bottom produces no less pump pressure than a bit after a certain depth, depending on the rig, is passed. There may be a slight but unrecognizable increase in engine revolutions per minute and strokes per minute on the pump. At least, the possibility of such an increase in the pump strokes is great enough to warrant checking the strokes per minute often enough to determine the normal rate so that any speeding up of the pump can be recognized. The reduction in rate of penetration might be credited to a change in formation or wearing out of the bit so this symptom is not positive. In view of lack of positive indications from the other two symptoms, however, a reduction in the rate of penetration becomes the reason for a thorough investigation to determine the cause.

There are other indications of a pumped-out place in the drill pipe available on many engine-driven rigs. One is the engine tachometer and the other is the engine-manifold-pressure (vacuum) gauge. Most rigs have one or the other and a number of rigs have both. The former will show any small increase in engine revolutions due to a reduction in the back-pressure against the pump. The latter will reflect any reduction in the load on the engine even though it does not increase its revolutions per minute, caused by a lessening of pump pressure requirements. Together the two provide the only positive indication of impending trouble as an increase in revolutions per minute without a decrease (lesser reading) on the vacuum gauge shows the engine load has been reduced. Likewise an increase on the vacuum gauge (higher reading) without a decrease in revolutions per minute also spells trouble. Such discrepancies accompanied by a reduction in the rate of penetration call for pulling of the drill pipe and a search for a hole in it.

The only easily recognized symptom of a pipe break-off on the mechanical rig is a reduction in the weight of the drill string as shown by the weight indicator. There may be no discernible increase in rotary table revolutions per minute, no reduction in pump pressure, no recognizable speeding up of the pump. Unfortunately, some weight indicators are not sensitive enough to small changes in weight to reflect the loss; in addition the reading of some weight indicators is affected by exterior conditions. There have been cases where drillers have weighed the pipe several times in an effort to determine if it remained intact and they still were not sure.

Again, the engine tachometer and vacuum gauge, plus a rotary table tachometer, are the most practical indicators of the trouble. The reduction in load is generally sufficient to produce an appreciable increase, as shown by these gauges, in engine speed and manifold pressure. The changes would not be discernible to the eye and ear of the driller, however.

Automatic recording of the functions of a drilling rig, such as in mud logging, have resulted in the prevention of numerous fishing jobs and have shown when pipe break-offs took place but it is very unlikely that any great immediate increase in rig instrumentation will take place in the near future. Manual recording of the values shown on the tachometer and vacuum gauge appears warranted, however. During most of the drilling of wells at the present time the driller is required to record drilling time and the setting down of vacuum gauge and tachometer readings would add no great strain.

One of the indications of a pump-out or break-off not mentioned above because of difficulty of definition should not be overlooked. It probably could best be called the psychic indications of trouble. Unfortunately a disposition on the part of many individuals to claim undue credit and abilities prevents this indication from being given its proper

*Simons Bros. Drilling Company, Tulsa, Oklahoma

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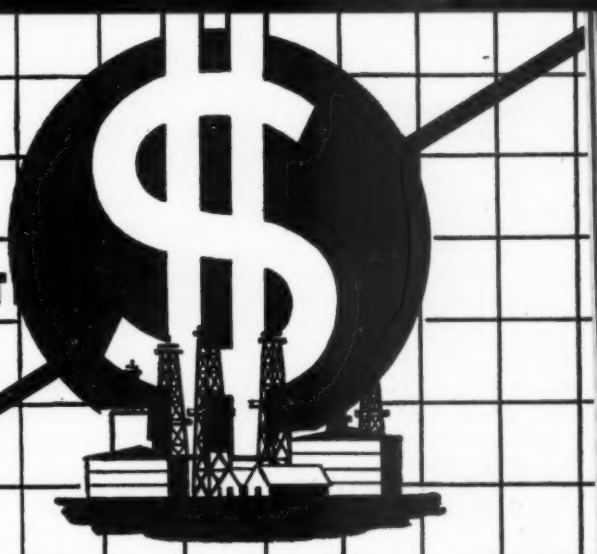
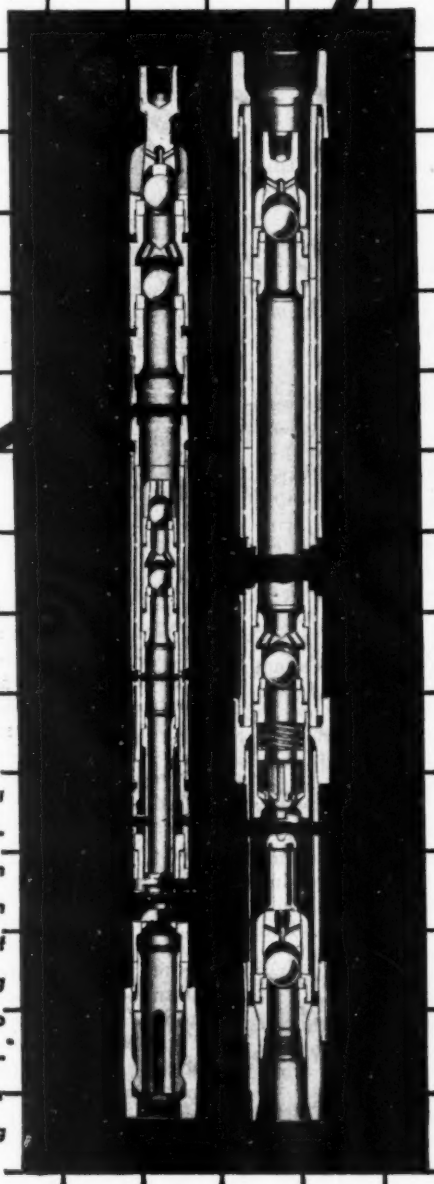


depend on UNDERGROUND *equipment*



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place. Quite frequently a driller will report that he "knew there was a wash-out or a break in the pipe so he came out of the hole" without telling just how he knew. If pressed, he may pick the necessary symptoms out of the air rather than admit he was acting on a hunch.

The feeling of impending disaster, or that all is not well on a rig, should not be ignored. It is just as good an indication of trouble as any of the instruments on a rig. Failure of the various gauges to show definite changes may be due to lack of proper sensitivity or to poor adjustment and yet the overall "feel" of the rig simply will not be right. If all the checks of conditions show there are no positive indications of trouble and the feeling of doom persists, pulling of the drill pipe is warranted. Quite frequently something amiss will be discovered although it may not be what was originally suspected. At least the fact that all is well is definitely established. On the other hand, staying in the hole may result in a break-off of the pipe or the running on a fish.

Aside from checking the weight of the drill pipe and the various gauges to determine if the drill pipe is still together one of the best assurances is to test the action of the bit. If the bit will drill off and if a uniform increase in penetration is obtained as weight is applied and if the engines are required to deliver more power as weight and speed are applied to the bit, the drill stem is probably intact.

Particular caution is required where the drilling is rough and the drill stem has a tendency to bind and bounce. The strain on the drill pipe is increased and a weak place in the pipe may give way. Bouncing and snapping of the drill stem may then be credited to the formation instead of to a jagged break-off. On the other hand, sudden freeing of the drill stem after a session of rough drilling may be due to a smooth break-off and the riding of the upper part of the string on top of the fish. Lack of penetration of the bit indicates trouble.

In cases where a mechnical rig is equipped with only a weight indicator and a mud pump gauge operation of the engines just below the maximum speed may be helpful in discovering twist-offs when they happen. The increase in engine speed to the governed rate may then be noticeable to the driller. ★ ★ ★

Executive changes

C. J. Coberly, president of Kobe, Incorporated, has announced changes in executive positions in keeping with the enlarged facilities and expanding activities of the company. A. M. Smith has been appointed to the new position of production manager. W. C. Marston continues as assistant treasurer, H. K. Browning as general sales manager, and R. F. McArthur as chief engineer.

Smith's new appointment places him in charge of all manufacturing activities and effects a consolidation of these interests involving the company's hydraulic pumping equipment, pipe perforating, precision gauge and ordnance divisions.

Natural Gas and Natural Gasoline Terminology

For some time, according to a number of forward-thinking individuals in the California natural gas and natural gasoline industries, there has been a recognized need for more clean cut definitions of some of the terms commonly used by both industries. This need, points out this group of gas and gasoline men, is growing steadily with the continually increasing number of forms, questionnaires, and reports it is found necessary to prepare.

Time and again one finds that terms, the meaning of which at first seems obvious, are subject to several interpretations. Misunderstandings follow that might easily have been avoided had some list of generally accepted definitions or terminology been available.

As a step toward solution of this problem, the following natural gas and natural gasoline terminology has been compiled, based on a study of the ideas, suggestions, and opinions offered by a number of men in the natural gas and gasoline industries in California who sincerely believe that it is a step in the right direction. It is thought to be comprehensive though brief and each definition has been framed with consideration for other definitions that might be related. Although not intended to be accepted as final, it is offered to the industry at large for such use as those interested may wish to make of it in the solution of a common problem.

TERMINOLOGY

Natural gas: Any gas of natural origin consisting principally of hydrocarbons.

Formation gas: Any natural gas producible directly from its original source.

Wet gas: Any unprocessed natural gas that is producible from stratum containing crude petroleum and/or condensate (specifically, the term "wet" bears no inference as to the water content of the gas.)

Dry gas: Any natural gas that is producible from a stratum that does not contain crude petroleum and/or condensate.

Residue gas: Any natural gas remaining after the extraction of liquid products from wet gas. (The term dry gas has often been used in lieu of the preferable term residue gas.)

Shrinkage: The reduction in volume of the wet gas input to a processing plant due to the extraction of liquid products. (Note: Does not include plant fuel.)

Plant fuel: Any natural gas used for fuel in the processing plant.

Processing plant: Any plant that is used to process natural gas for the extraction of hydrocarbons and/or other substances.

Natural gasoline plant: A processing plant operated for the purpose of extracting natural gasoline and/or lighter hydrocarbons from wet gas.

Condensate plant: Any processing plant extracting liquid hydrocarbons from a wet gas containing condensate.

Compressor plant: Any plant for compressing natural gas or other hydrocarbon vapors. It is a unit of a processing plant if used for compressing wet gas that is being processed for the extraction of liquids.

Circulated gas: Any natural gas that is used to produce fluid from wells and that is immediately returned from the well (such as gas-lift gas), or that rapidly migrates to an adjoining well and is currently produced along with the formation gas produced by such a well.

Repressure gas: Any natural gas injected into a formation capable of producing crude petroleum and/or condensate to aid in maintaining pressure in an underground reservoir for the purpose of assisting in the future recovery of any fluid (pressure maintenance).

Storage gas: Any natural gas returned to an underground reservoir for the purpose of creating a natural gas reserve but not intended for the purpose of aiding in the recovery of any fluid.

Unconserved gas: Any natural gas that is blown to the air.

Vapor: Any gas evaporated from liquid hydrocarbons or extracted from wet gas within the processing plant that requires further processing for the recovery of liquid products.

Natural gasoline company: Company engaged in the extraction of natural gasoline.

Gas company: A company engaged in the business of purchasing and reselling dry gas or residue gas.

Liquefied petroleum gas (L.P.G.): Any hydrocarbon mixture, the predominant components of which consist of normal butane or isobutane, or propane, or mixtures thereof, in any ratio and which is produced and marketed for fuel purposes.

Natural gasoline: Any liquid hydrocarbon mixture that contains substantial quantities of pentanes and heavier, and has been extracted from natural gas and has an end point not greater than that of motor gasoline.

Condensate: The liquid produced by a reduction of pressure, which may be accompanied by a reduction of temperature (retrograde condensation) from a high pressure wet gas that existed in the formation in a single gaseous phase.

Liquefied gas stock: Liquefied hydrocarbons consisting of isopentane or lighter materials substantially pure, or mixtures in any ratio that have been produced for further processing.

Standard cubic foot: A standard cubic foot of gas is that quantity of gas that occupies one cubic foot at standard conditions, i.e., at a temperature of 60°F. and an absolute pressure of 14.73 lb. per sq. in.

M. C. F.: 1000 standard cubic feet.

★ ★ ★

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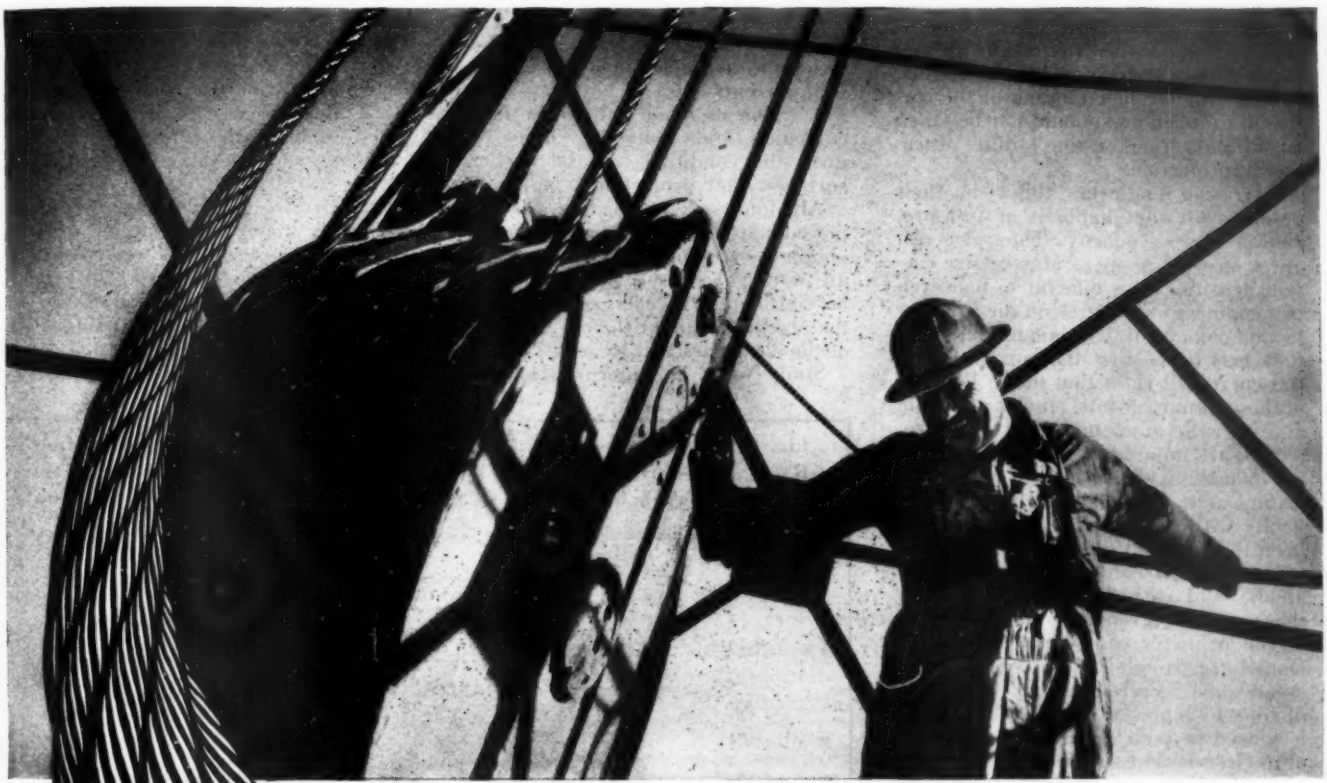

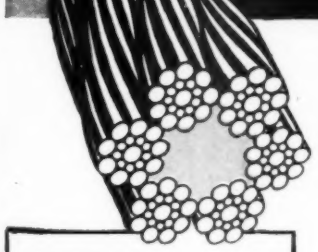

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P 615.635.4

Method of Studying Anodic, Cathodic Areas Under Cathodic Protection*

By OTHA C. RODDEY and LYLE R. SHEPPARD†

Corroding unit composed of two electrodes in a single electrolyte used effectively

IT has been evident for some time that there is much to be learned of the electrical phenomena occurring when underground metal structures are cathodically protected. Quite often when cathodic protection is applied the results are not as predicted and expected. This is due to inadequate understanding of the corrosion problem and should not be taken as an indication of the failure of cathodic protection.

Corrosion engineers differ in their opinions of what happens at full protection current density. They also disagree on what happens at excessive current densities. It is difficult to find even two engineers who agree on the full protection point or its determination, though they may agree that the current-potential curve will show that point. Because of these disagreements, studies of anodic and cathodic areas under cathodic protection are important.

For making such studies a method of testing must be selected. The chief difficulty with such laboratory studies has been the artificial creation of a suitable corroding unit composed of *controlled* anodic and cathodic areas similar to those on underground structures.

The principle of the two electrolyte Daniel gravity cell has been suggested to create such a corroding unit. One piece of iron, to represent the corroding unit, is placed in both electrolytes. One end of the iron becomes anodic and the other cathodic. However, as the current density of the corroding unit cannot be controlled, and the anodic and cathodic areas vary with time as the test proceeds, this method cannot be used.

A corroding unit composed of two electrodes in a single electrolyte can be used. One electrode is made anodic and the other cathodic by an external battery. The corroding currents can be controlled by external resistances. A controlled protecting unit is combined with the corroding unit to make the studies. (See Fig. 1). Such an arrangement allows studies to be made of the electrical reactions and current distributions on the surfaces of the corroding anode and cathode while both are under cathodic protection.

In making the studies the following four sets of readings are taken.

1. With all circuits closed but with no power from either battery. This gives the natural currents, if any, between all the electrodes.

2. Same as 1 but with power on the corroding unit. This gives the corroding conditions before any protection is applied.

3. Same as 1 but with power on the protecting unit only. This gives the conditions with protection against the natural currents only.

4. Same as 1 but with power on both corroding and protecting units. This gives the conditions on the corroding surfaces after protection is applied.

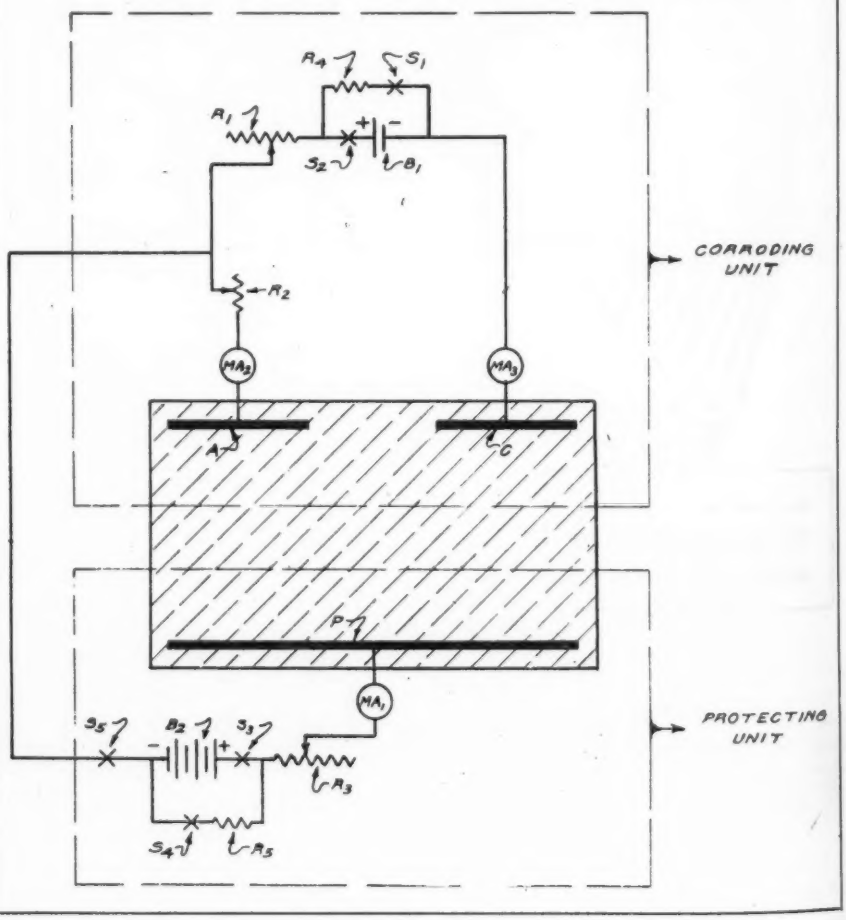
All four sets of reading are taken periodically during the tests. In order to obtain the true picture under protection all of the above sets of readings must be considered. In each set of readings the algebraic sum of the currents on all of the electrodes will be zero.

Study No. 1. The interpretation of the concept of superposition of electric currents has left some doubt whether the corroding current continues to flow when cathodic protection is applied. Anyone can prove to himself that it does not continue to flow but is cancelled by the protecting current. For example, connect the positive terminal of each of two batteries of equal voltage to the negative terminal of the other with a 12-in. piece of resistance wire. The mid-points of the two resistance wires are now connected with a 3-in. piece of the same size resistance wire. The 3-in. wire will not get hot if both batteries are in circuit, but with either of the batteries disconnected it will get hot. If the opposite currents were not cancelled in the short wire when both batteries are in circuit, the short wire would get twice as hot as it does with one battery in circuit, but because it remains cool the currents must cancel each other. (See drawing top next page.)

This simple test is mentioned to clear any doubt of the interpretation of the concept of superimposed electric currents.

Study No. 2. This is a study of the effect on current distribution by increasing the cathodic area of a corroding unit. The apparatus shown in Fig. 1 was used with three cathodes, instead of one, each equal in area to the corroding anode. The electrolyte was 0.1 normal sodium chloride solution. Doubling the cathodic

Fig. 1. A, P—anodes in solution. C—cathode in solution. B_1, B_2—batteries. R_1, R_2, R_3—variable resistors. R_4, R_5—fixed resistors equal to internal resistance of each battery. S_1, S_2, S_3, S_4, S_5—switches. Ma.—milliammeters.



*Presented before National Association of Corrosion Engineers, Houston, Texas, April, 1944.

†Interstate Natural Gas Company, Inc., Monroe, Louisiana.

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1941

Franks Manufacturing Corporation
Tulsa, Oklahoma

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The first 12 months we had this unit, it worked on 58 wells. Sixteen of these wells were clean-out jobs and comparable to wells which have taken competitive units from two weeks to a month to complete. Eleven of these wells were deepening jobs - anywhere from 500 to 1,500 feet. Ten were following up roteries, in this case saving 40 days drilling time on two roteries. The other jobs were tubing, running and resetting packers.

1944

TRINITY DRILLING COMPANY
KIRBY BUILDING
DALLAS, TEXAS

April 3, 1944

Franks Manufacturing Corporation
Drawer 3218, Whittier Station
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We have been using your 5000 Double Drum all-purpose Servicing Unit in combination with your Telescoping Derrick for drilling in Southwest Texas. We have drilled a number of wells 5,000 feet, cutting 7-7/8" size hole. We were averaging one of these wells each 15 days.

We have written you before of other satisfactory service this unit has rendered.

Yours very truly,

President

C:MD/rm

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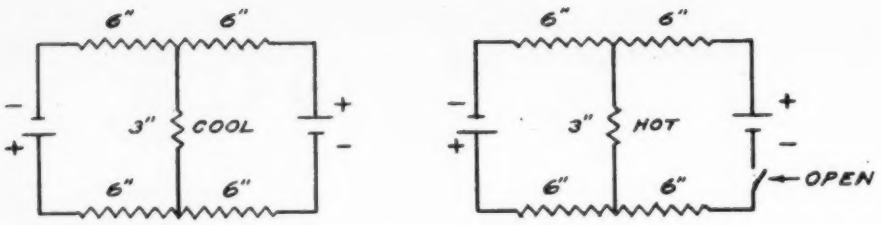

area increased the corroding current 6.7 per cent; tripling the cathodic area increased the original corroding current 16.7 per cent. The cathode nearest the anode carries 50 per cent more current than either of the farther ones when all 3 were in circuit. This study shows that the smaller anodic area is the greater controlling factor of current volume in a corroding cell. It also shows that the nearer cathodic area takes a greater proportion of the current than the further areas.

Study No. 3. This study was made to establish a method for determining the full protection point when cathodic protection is applied to a corroding unit. The apparatus was the same as shown in Fig. 1. In order to have no iron in the solution except that from the corroding anode, the protecting anode was made carbon. The electrolyte was 0.1 normal sodium chloride solution with 10 drops of potassium ferrocynide added to each 1000 cc. of the solution. The potassium ferrocynide turns blue at the corroding anode as long as any iron goes into solution from the corroding anode. The electrolyte was replaced after each test until no color change occurred with increased protecting current density. Where it can be used, this colorimetric method of determining the full protection point of the corroding anode is more accurate than the weight loss method.

According to the colorimetric method, complete protection of the corroding anode occurred between points 3 and 4 on Fig. 3. Between these two points current stopped flowing from the corroding anode to the solution and started flowing from the solution to the corroding anode. This indicated experimentally that complete protection was established at the point where current stopped flowing from the corroding anode. However, this determination of the full protection point could not be used on any underground corroding unit having both anodic and cathodic areas because the current flowing to the anodic area could not be isolated and measured separately from that flowing to the cathodic area. Consequently, some method that takes both

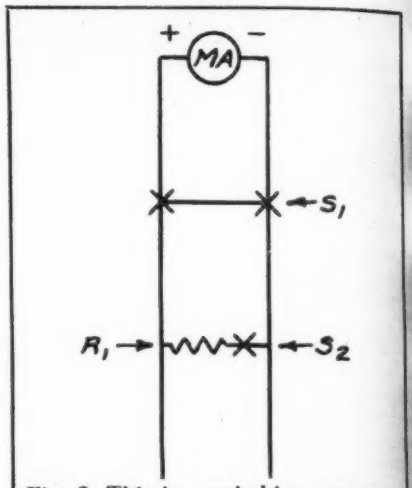

Fig. 2. This is a switching arrangement for using the same instrument for measuring all similar currents or voltages, without opening any circuit. During tests either S_1 or S_2 must always be closed, and neither is opened without the others being closed first. This assures that the same resistance is always in the measuring circuit at all times except at the instant both switches are closed, when it becomes half as much. This will not depolarize any coupons being measured, but rather tend to increase the polarization. Ma.—instrument. S_1—double pole switch. S_2—single pole switch. R—fixed resistance equal to internal resistance of instrument.

Fig. 3.

Fig. 4.

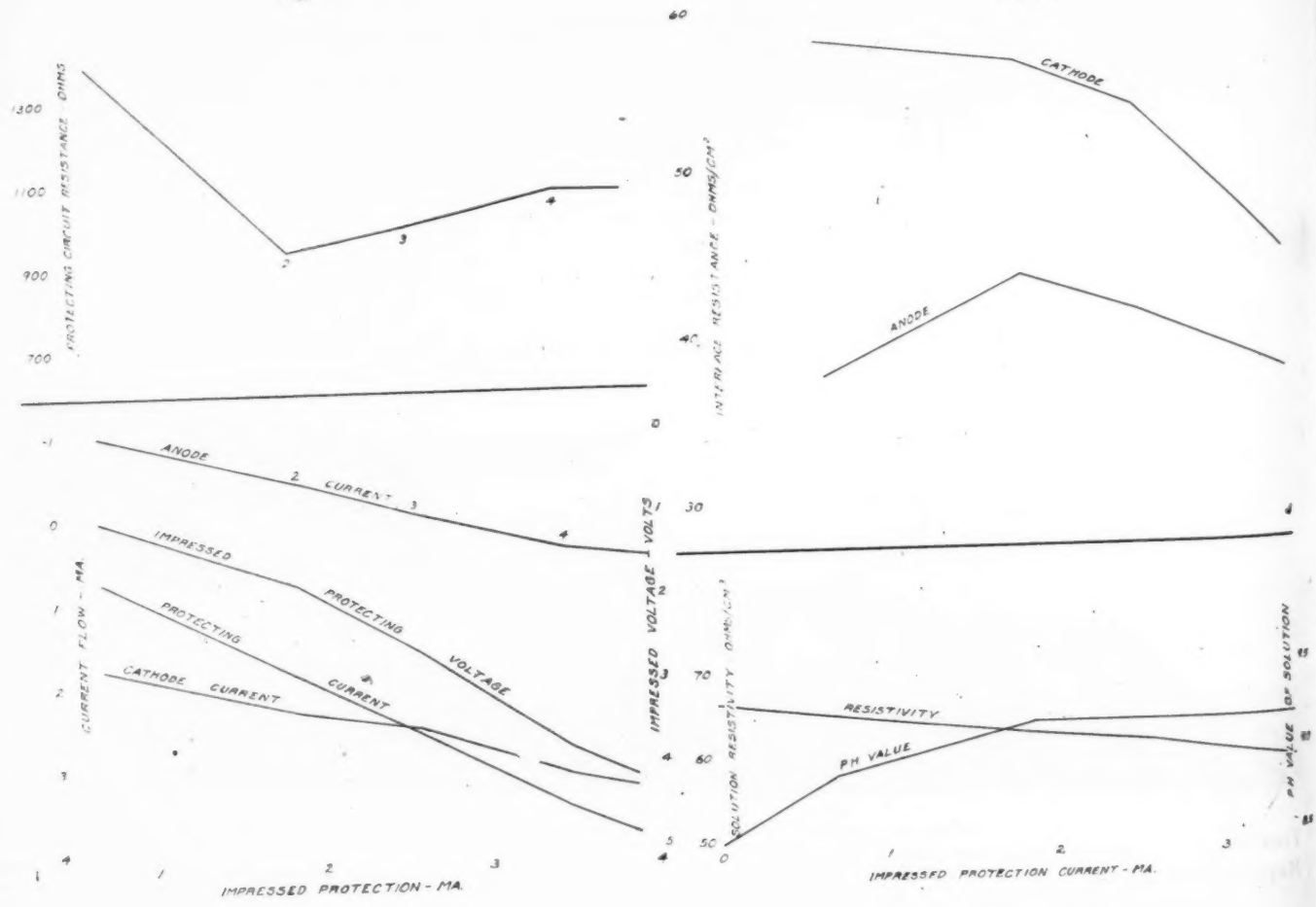

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TABLE 1

	Start of test	After 44 hr.	After 114¼ hr.
Solution resistivity, ohms/cm³	58.8	54.4	49.4
Interface resistance of anode, ohms/cm²	37.1	52.3	56.8
Interface resistance of cathode, ohms/cm²	40.3	50.3	67.1
Protection circuit resistance, ohms	1160	1140	1085
Current from anode to solution, ma.	.050	.025	.000
Current to cathode from solution, ma.	2.650	2.650	2.750
Total protecting current, ma.	2.700	2.675	2.750

anodic and cathodic areas into consideration must be used.

It was found that the total protecting circuit resistance (calculated from the total impressed voltage and amperage) made a decided change at a point (point 2, Fig. 3) just before full protection was established according to the colorimetric method. As the total impressed protecting voltage and amperage can be measured on any corroding unit of this type, it was thought that this sudden change in resistance could possibly be used to locate the full protection point; especially after some time had been allowed for the full polarization of the corroding anode. Thereafter, the protecting current was reduced and left at the point (3 on Fig. 3) just below the protection point (4) as determined by the colorimetric method. After 114¼ hr. the current flowing from the corroding anode had become zero. (See Table 1). The interface resistance of both the corroding anode and cathode had increased. These related facts indicate that the anode was gradually being polarized and that probably the point of sudden change in resistance of the protecting circuit does locate the full protection point.

Fig. 3 also shows how the protecting current is divided between the anode and the cathode of the corroding unit.

Study No. 4. This study of the solution and interface resistances used the same data as Study No. 3. The trends of the interface resistances on the corroding anode and cathode can be seen on Fig. 4. As protection is increased the interface resistances of the anode and cathode tend to come to equal values, or in other words when full protection is reached the polarization on each is due only to the protecting current. Time is also a great factor, often not given proper consideration, in this equalization of polarization on the different parts of the corroding unit. (See Table 1.)

The resistivity of the electrolyte decreases with increased protection and with time. The electrolyte also becomes more alkaline. However, the greatest increase in alkalinity seems to have occurred as soon as protection was applied, as there was less and less change with time. This may have been due to the saturation points being reached quickly in a limited space.

The solution resistivity should be considered in all tests since it is a sizeable factor in comparison to the interface resistance. A comparison of the resistance curves in Fig. 4 shows this.

Conclusions. 1. When two direct currents flowing in opposite directions are superimposed in one circuit they cancel each other and only the resultant current flows, not the full value of both currents.

2. The anodic area, usually being smaller than cathodic area, is the main controlling factor in current flow in a corroding unit or cell.

3. The colorimetric method (using potassium ferrocynide for iron electrodes) for determining the full protection point in a solution is probably more accurate than the weight loss method.

4. Indications are that the calculated protecting circuit resistance-current density curve shows the full protection point more readily than the potential-current density curve.

5. At full protection the corroding anode and cathode have equal interface resistances and polarizations.

6. The electrolyte increases in alkalinity and electrical conductivity with both increased protection and time.

7. Electrode interface resistances can and should be eliminated in measuring solution resistivity.

8. Tests in limited spaces should not be taken to give absolute values for use in unlimited spaces but only to show trends.

9. Time is a factor not properly considered in cathodic protection.

APPENDIX

Fig. 1 (Continued). This figure shows the electrical circuits of the combined corroding and protecting units.

Corroding unit. This unit is formed of the battery B_1, and the measured anode A and cathode C. The intensity of corrosion is controlled by the variable resistors R_1 and R_2, and measured by the milliammeters Ma_2, and Ma_3. R_5 must be adjusted so that it is always equal to the sum of R_1 and R_4. This adjustment assures that any change on the corroding anode or cathode while under protection can be noticed directly because the resistances of the two parallel parts of the protecting circuit are equal except at the surface of the corroding anode and cathode.

The corroding battery shunting switches S_1 and S_2 are really one switch closing one circuit as the other is opened. Fixed resistor R_4 is inserted so that the shunting arrangement does not change the circuit resistance.

Protecting unit. The protecting unit is similar to the corroding unit except that the anode and cathode of the corroding unit become the cathodes of the protecting unit. The protecting anode is made larger in surface than the combined area of the corroding anode and cathode so that it will not be the limiting factor in determining the current flow in the protecting circuit.

The milliammeters are so placed that they will always measure the resultant current flowing into or out of each electrode.

The potential difference readings in the solution are taken with a high resistant steel exploring electrode and a potentiometer voltmeter. The same electrode is used for all measurements. Copper sulphate electrodes tend to plate copper on the cathodes.

Resistance measurements. Resistance measurements between A, P, C, can be taken with an a-c. bridge without disturbing the tests. This is much simpler than trying to calculate the various changes of resistances from current and voltage measurements. Even so the measurements must be properly interpreted and corrected to arrive at the true interface resistances of the individual electrodes. Consideration must be given to the various parallel circuits when measurements are taken between any two electrodes. For example, with both corroding and protecting units operating, the following conditions exist: (See Fig. 1).

Let Ra = interface resistance of corroding anode, A,
Rp = interface resistance of protecting anode, P,
Rc = interface resistance of cathode, C,
Rs = solution resistance between electrodes,
Rpa = measured resistance between P and A,
Rpc = measured resistance between P and C, and
Rac = measured resistance between A and C

Then the following equations are true:
From measurement between A and C:

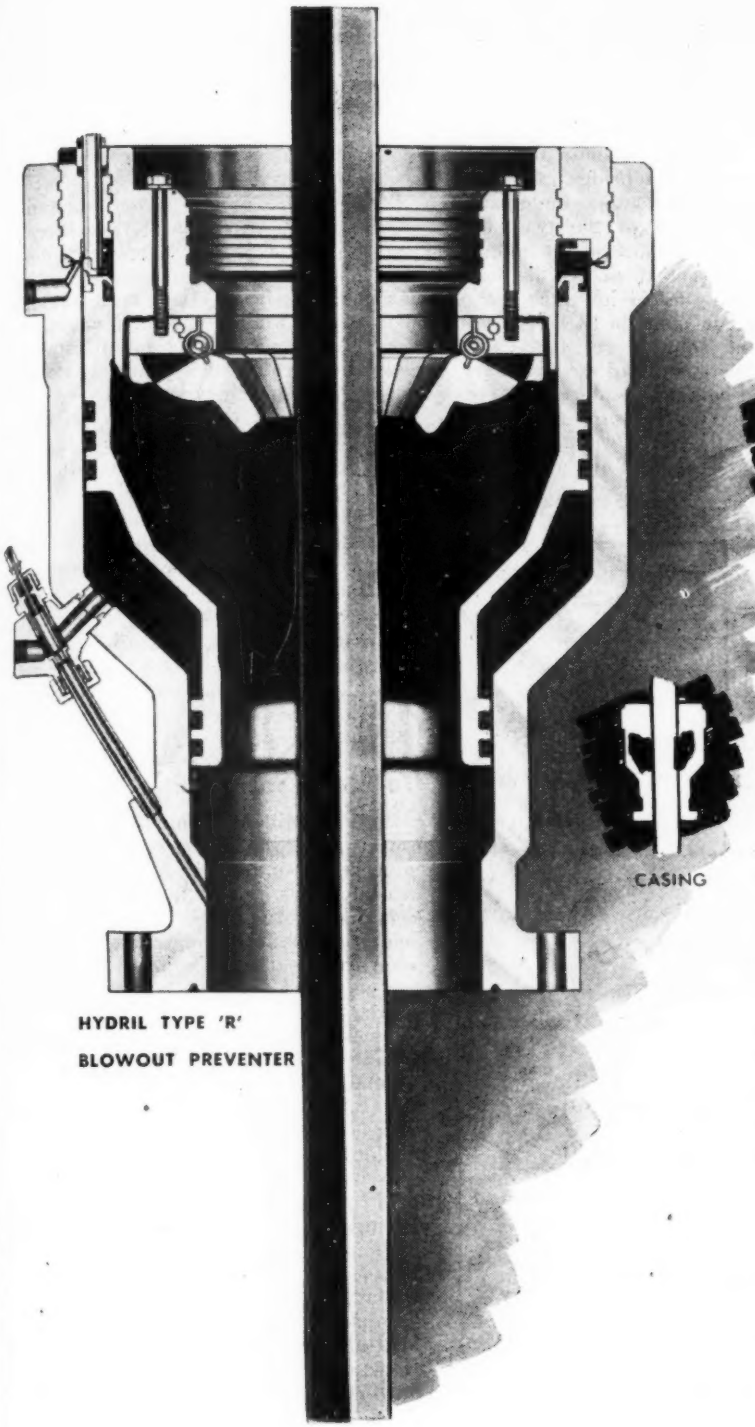
$$\frac{1}{Rac} = \frac{1}{Ra + Rs + Rc} + \frac{1}{R_2 + \left[\dfrac{(R_1 + R_4)\,(R_5 + R_3 + Rp + Rs)}{R_1 + R_3 + R_4 + R_5 + Rp + Rs}\right]} \quad . \quad . \quad (1)$$

From measurement between P and C:

$$\frac{1}{Rpc} = \frac{1}{Rp + Rs + Rc} + \frac{1}{(R_1 + R_4) + \left[\dfrac{(R_3 + R_5)\,(R_2 + Ra + Rs)}{R_2 + R_3 + R_5 + Ra + Rs}\right]} \quad . \quad . \quad (2)$$

From measurement between P and A:

$$\frac{1}{Rpa} = \frac{1}{Rp + Rs + Ra} + \frac{1}{R_2 + \left[\dfrac{(R_3 + R_5)\,(R_1 + R_4 + Rc + Rs)}{R_1 + R_3 + R_4 + R_5 + Rc + Rs}\right]} \quad . \quad . \quad . \quad (3)$$



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From these three equations the interface resistance (Rp, Ra, Rc) of each of the electrodes can be expressed in terms of the solution resistance (Rs) and the a-c. bridge measurements (Rac, Rpc, Rpa). A study of these interface resistances under protecting conditions is necessary to understand properly the phenomena of protection. If greater external resistances are used for R_1 and R_2 the measurements between electrodes become more nearly of series circuits and equations are simplified to:

$$Rac = Ra + Rs + Rc \quad . \quad . \quad . \quad (1)$$
$$Rpx = Rp + Rs + Rc \quad . \quad . \quad . \quad (2)$$
$$Rpa = Rp + Rs + Ra \quad . \quad . \quad . \quad (3)$$

Solution resistivity and resistance (Rs). Solution resistivity can be measured by inserting two closely fitting electrodes into a glass tube filled with the solution. An a-c. bridge resistance reading is taken between the electrodes. One electrode is then moved a known distance away from the other in the solution, and another a-c. bridge resistance reading taken. Both readings include the interface resistances of the two electrodes and the resistance of the column of solution between them. As the solution is homogeneous the interface resistances will be the same in both readings and only the solution resistance will change, by the amount of the resistance of the added column of solution. Therefore, the lesser reading subtracted from the greater will give the solution resistance of a known length of the column. From this and the cross-sectional area of the column, the resistivity of the solution may be calculated. This method of measuring the resistivity of a solution is different from most in that the interface resistances of the electrodes are considered and eliminated.

Obviously Wenner's equation, Resistivity $= 2\pi$ x distance x resistance, is not applicable in a confined laboratory test. Wenner's equation applies to an unlimited space whereas a laboratory test is in a limited space. However, an approximation of the solution resistance, Rs, can be calculated from the solution resistivity, the distances between the electrodes, and the areas of the electrodes. Solution resistance $=$

$$\frac{\text{distance} \times \text{solution resistivity}}{\text{area}}$$

It is to be understood that this value is not absolutely correct, but is sufficiently correct to determine the trends of interface resistances on the corroding unit electrodes.

Acknowledgment. The authors wish to express their appreciation to Raymond Russell for his assistance in checking electrical circuits and constructing testing equipment. ★★★

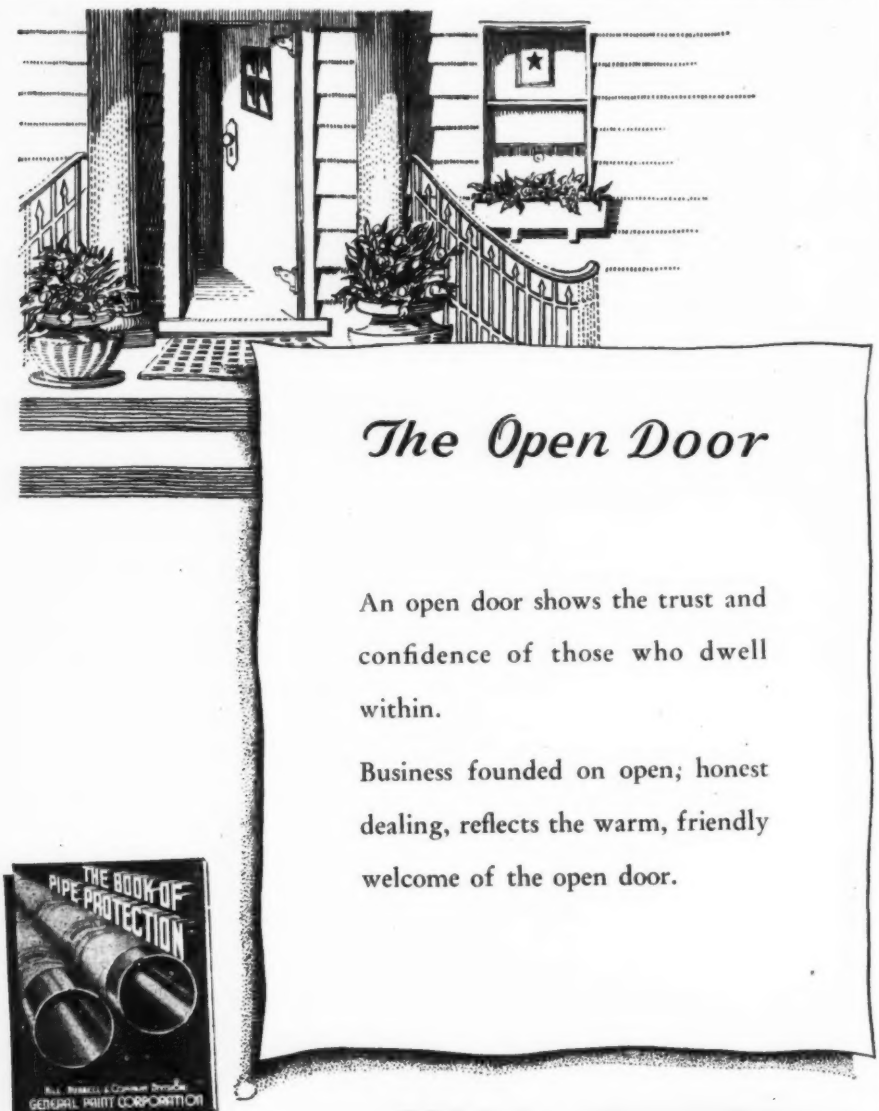
To study corrosion

In a coordinated effort to combat the serious corrosion being encountered in pipe and fittings of high pressure condensate wells, the Natural Gasoline Association of America is sponsoring a cooperative research program having as its objective the determination of the causes and means of eliminating this corrosion.

According to William F. Lowe, N.G.A.A. secretary, it is expected the project will be continued for at least 3 years with an annual budget of $20,000.

T. S. Bacon, director of research, Lone Star Producing Company, Dallas, was made chairman of the Corrosion Research Project Committee. Other members of this group include the following: Dr. R. G. Atkinson, Shamrock Oil and Gas Company, Amarillo; W. A. Bowser, Atlantic Refining Company, Dallas; Walter Dayhuff, Standard Oil Company of California, Los Angeles; J. M. Dillon, Jr., Shell Oil Company, Inc., Houston; J. M. Flaitz, Distillate Production Corporation, Houston; R. W. French, Continental Oil Company, Ponca City; T. W. Johnson, Union Producing Company, Shreveport; W. W. McNeal, Jr., J. S. Abercrombie Company, Houston; T. W. McGuire, Cotton Valley Operators Committee, Cotton Valley; H. T. Pruett, Gulf Plains Corporation, Corpus Christi; P. A. Stagg, Superior Oil Company, Houston; C. R. Williams, The Chicago Corporation, Corpus Christi; R. T. Wilson, La Gloria Corporation, Corpus Christi, and Lester Wood, Phillips Petroleum Company, Bartlesville.

Other contributing companies whose official representatives have not been named include Arkansas Fuel Oil Company, Humble Oil and Refining Company, Ohio Oil Company, Magnolia Petroleum Company, and Stanolind Oil and Gas Company.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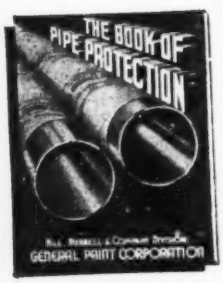

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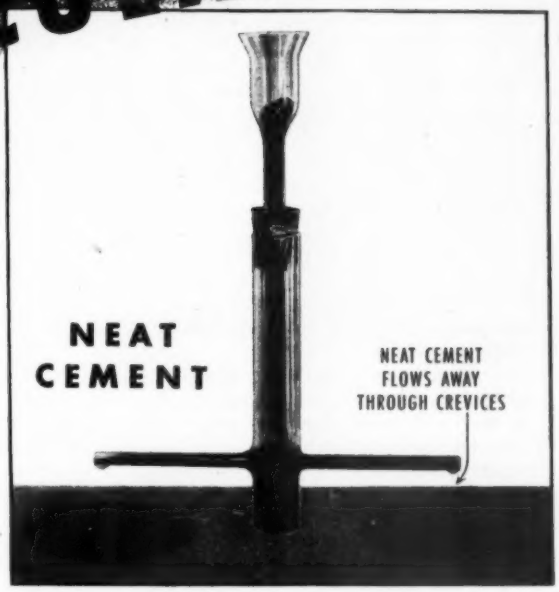
AQUAGEL Cement tends to pile up and bridge the entrance to caverns, while neat cement seeks its own level and flows away like water. See examples at right.

AQUAGEL Cement has many other advantages which make it unequaled for solving lost circulation problems and for cementing casing, but its properties of high angle of repose and gelation save operators many hours of time and large quantities of cement slurry when sub-surface crevices are encountered.



The apparatus above represents a well drilled into a badly fractured or creviced zone (glass-tubing cross arms represent crevices), the funnel tubing being the "casing." Neat cement on being poured down the funnel tube fills the bottom of the glass "hole" and flows out of the tubing. It continues to flow out of the tubing while slurry is added to the funnel. Note flat angle of repose. This demonstrates why large crevices are difficult or impossible to seal with neat cement.

The same apparatus as used for neat cement shows the results of pouring AQUAGEL Cement slurry into the funnel tube. The slurry piles up, seals the cross arms and allows the slurry to reach a desirable height in the hole. Note the steep angle of repose inside the tubing. This shows the plug-like flow of AQUAGEL Cement.

PATENT LICENSES, unrestricted as to sources of supply of materials, but on royalty bases, will be granted to responsible oil companies and operators to practice inventions of any and/or all of United States Patents Numbers 1,807,082; 1,991,637; 2,041,086; 2,044,758; 2,064,936; 2,094,316; 2,119,829; 2,214,366; 2,294,877; 2,304,256 and further improvements thereof. Applications for Licenses should be made to Los Angeles office.

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United States and Great Britian Sign World Petroleum Agreement

THE complete text of the agreement on petroleum between the government of the United States of America and the government of the United Kingdom of Great Britain and Northern Ireland is as follows:

▼**Introductory article.** The Government of the United States of America and the Government of the United Kingdom of Great Britain and Northern Ireland, whose nationals hold, to a substantial extent jointly, rights to explore and develop petroleum resources in other countries, recognize:

1. That ample supplies of petroleum, available in international trade to meet increasing market demands, are essential for both the security and economic well-being of nations;

2. That for the foreseeable future the petroleum resources of the world are adequate to assure the availability of such supplies;

3. That such supplies should be derived from the various producing areas of the world with due consideration of such factors as available reserves, sound engineering practices, relevant economic factors, and the interests of producing and consuming countries, and with a view to the full satisfaction of expanding demand;

4. That such supplies should be available in accordance with the principles of the Atlantic Charter and in order to serve the needs of collective security;

5. That the general adoption of these principles can best be promoted by international agreement among all countries interested in the petroleum trade whether as producers or consumers.

▼**Article I.** The two governments agree that the development of petroleum resources for international trade should be expanded in an orderly manner on a worldwide basis with due consideration of the factors set forth in paragraph 3 of the introductory article and within the framework of applicable laws or concession contracts.

To this end, and as a preliminary measure to the calling of the international conference referred to in Article II below, the two governments will so direct their efforts, with respect to petroleum resources in which rights are held or may be acquired by the nationals of either country:

1. That, subject always to considerations of military security and to the provisions of such arrangements for the preservation of peace and prevention of aggression as may be in force, adequate supplies of petroleum shall be available in international trade to the nationals of all peaceable countries at fair prices and on a non-discriminatory basis;

2. That the development of petroleum resources and the benefits received therefrom by the producing countries shall be such as to encourage the sound economic advancement of those countries;

3. That the development of these resources shall be conducted with a view to the availability of adequate supplies of petroleum to both countries as well as to all other peaceable countries, subject to the provisions of such collective security arrangements as may be established;

4. That, with respect to the acquisition of exploration and development rights in areas not now under concession, the principle of equal opportunity shall be respected by both governments;

5. That the government of each country and the nationals thereof shall respect all valid concession contracts and lawfully acquired rights, and shall make no effort unilaterally to interfere directly or indirectly with such contracts or rights;

6. That, subject always to the considerations mentioned in paragraph 1 of this article, the exploration for and development of petroleum resources, the construction and operation of refineries and other facilities, and the distribution of petroleum shall not be hampered by restrictions imposed by either government or its nationals, inconsistent with the purposes of this agreement.

▼**Article II.** The two governments recognize that the principles declared in Article I hereof are of general applicability and merit adherence on the part of all countries interested in the international petroleum trade of the world.

Therefore, with a view to the wider adoption and effectuation of the principles embodied in this agreement they agree that as soon as practicable they will propose to the governments of other interested producing and consuming countries an international petroleum agreement which, inter alia, would establish a permanent international petroleum council composed of representatives of all signatory countries.

To this end the two governments hereby pledge themselves to formulate plans for an international conference to consider the negotiation of such a multilateral petroleum agreement. They also pledge themselves to consult with other interested governments with a view to taking whatever action is necessary to prepare for the proposed conference.

▼**Article III.** There are, however, numerous problems of joint immediate interest to the two governments, with respect to petroleum resources in which rights are held or may be acquired by their nationals, which must be discussed and resolved on a cooperative interim basis if the general petroleum supply situation is not to deteriorate.

With this end in view the two governments hereby agree to establish an international petroleum commission to be composed of eight members, four members to be appointed immediately by each government.

This commission, in furtherance of and in accordance with the principles stated in Article I hereof, shall consider problems of mutual interest to both governments and their nationals and, with a view to the equitable disposition of such problems, shall be charged with the following duties and responsibilities:

1. To prepare long-term estimates of world demand for petroleum, having due regard for the interests of consuming countries and expanding consumption requirements;

2. To suggest the manner in which, over the long term, this estimated demand may best be satisfied by production equitably distributed among the various producing countries in accordance with the criteria enumerated in paragraph 3 of the introductory article;

3. To recommend to both governments broad policies for adoption by operating companies with a view to effectuating programs suggested under the provisions of paragraph 2 of this article;

4. To analyze such short-term problems of joint interest as may arise in connection with production, processing, transportation, and distribution of petroleum on a world-wide basis, wherever the nationals of either country have a significant interest, and to recommend to both governments such action as may appear appropriate;

5. To make regular reports to the two governments concerning its activities;

6. To make, from time to time, such additional reports and recommendations to the two governments as may be appropriate to carry out the purposes of this agreement.

The commission shall establish such organization as is necessary to carry out its functions under this agreement. The expenses of the commission shall be shared equally by the two governments.

▼**Article IV.** To effectuate this agreement the two governments hereby grant reciprocal assurances:

1. That they will adhere to the principles set forth in Article 1, paragraphs 1 to 6 inclusive;

2. That they will endeavor to obtain the collaboration of the governments of other producing and consuming countries in the implementation of the principles set forth in Article I, and will consult, as appropriate, with such governments in connection with activities undertaken under Article III;

3. That upon approval of the recommendations of the commission they will endeavor, in accordance with their respective constitutional procedures, to give effect to such approved recommendations;

4. That each government will undertake to keep itself adequately informed

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of the current and prospective activities of its nationals with respect to the development, processing, transportation, and distribution of petroleum;

5. That each government will make available to the commission such information regarding the activities of its nationals as is necessary to the realization of the purposes of this agreement.

▼Article V. The two governments agree that in this agreement:

1. That words "country" or "territories"

(a) In relation to the Government of the United Kingdom of Great Britain and Northern Ireland, include, in addition to the United Kingdom, all British colonies, overseas territories, protectorates, protected States and all mandated territories administered by that government; and

(b) In relation to the Government of the United States of America, include, in addition to the United States, all territory under the jurisdiction of the United States;

2. The word "nationals" means

(a) In relation to the Government of the United Kingdom of Great Britain and Northern Ireland, all British subjects and British protected persons belonging to the territories referred to in 1 (a) above and all companies incorporated under the laws of any of the above-mentioned territories, and also companies incorporated elsewhere in which the controlling interest is held by any of such nationals;

(b) In relation to the Government of the United States of America, all nationals of the United States including companies incorporated under the laws of the territories referred to in 1 (b) above, and also companies incorporated elsewhere in which the controlling interest is held by any of such nationals;

3. The word "petroleum" means crude petroleum and its derivatives.

▼Article VI. This agreement shall enter into force upon a date to be agreed upon after each government shall have notified the other of its readiness to bring the agreement into force and shall continue in force until three months after notice of termination has been given by either government or until it is superseded by the international petroleum agreement contemplated in Article II.

In witness whereof the undersigned, duly authorized thereto, have signed this agreement.

Done in Washington, in duplicate, this eighth day of August, one thousand nine hundred and forty-four.

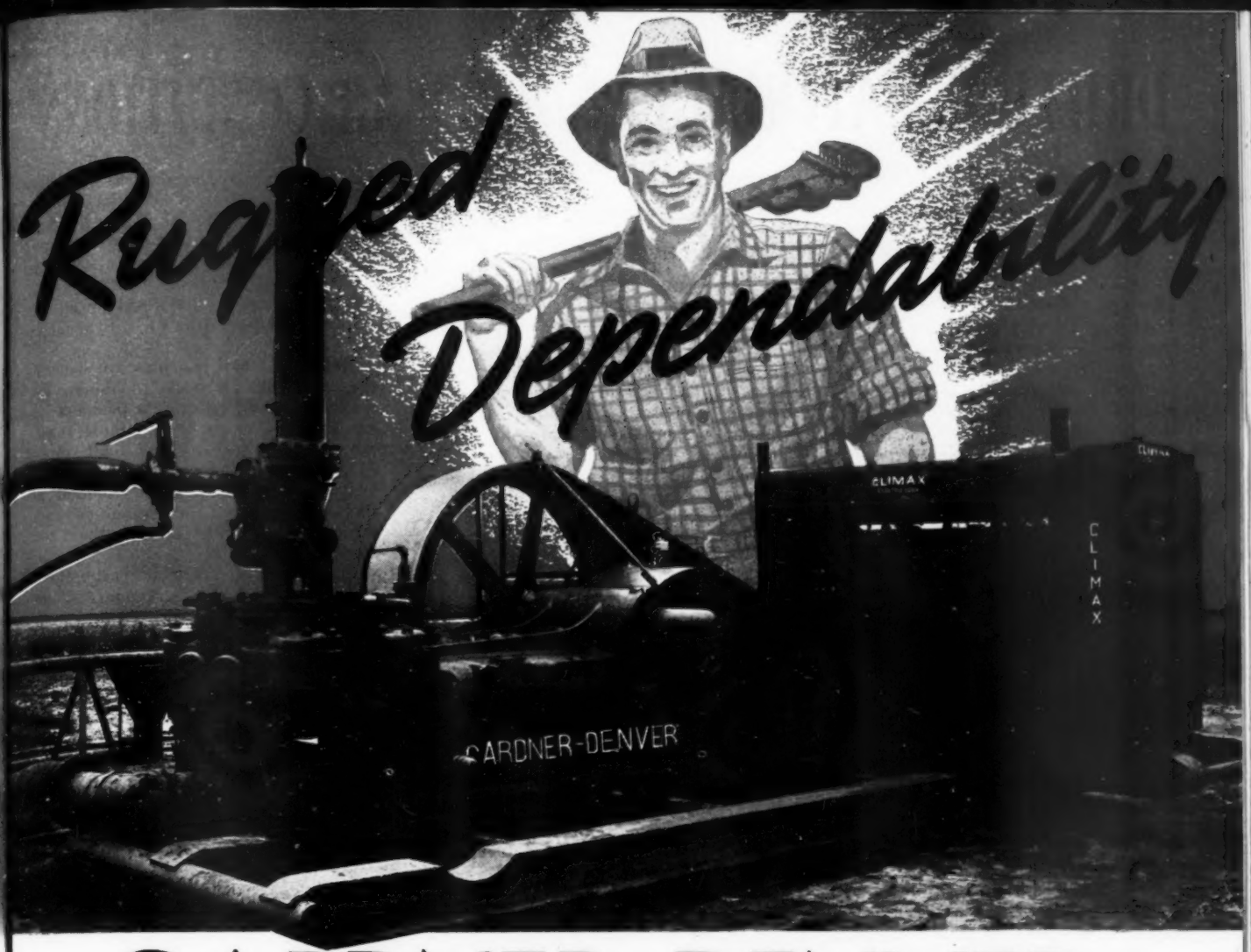
For the Government of the United States of America:

EDWARD R. STETTINIUS JR.,
Acting Secretary of State of the United States of America.

For the Government of the United Kingdom of Great Britain and Northern Ireland:

BEAVERBROOK,
Lord Privy Seal.

★ ★ ★



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SERVING THE OIL AND GAS INDUSTRIES

DRILLING MATERIALS UNDER WAR CONDITIONS*

Discussion of the industry's greatest difficulties, among which are lack of repair parts and manpower shortage

By W. H. MORRISON†

As a part of its 1944 program, the Mid-Continent District Committee on Drilling Practice canvassed numerous drilling contractors, oil companies, manufacturers, and supply companies in an effort to learn just what are the drilling industry's greatest difficulties. All those contacted were extremely cooperative, expressed themselves without reserve and in many instances, produced records to substantiate their statements. Since in most cases, we were requested not to quote or reveal the source of information, this report must deal with generalities. The statements contained herein are supported by the facts made available to the committee.

The continued upswing in drilling activity is causing more and more headaches to the drilling industry despite the somewhat relaxed restrictions on materials. To maintain this high rate of drilling activity, the industry must receive more consideration in the following respects:

(a) Improved quality of materials,
(b) Greater quantity of repair parts for stocks,
(c) Improved service facilities (machine and repair shops, transportation and dirt moving equipment, etc.)
(d) Manpower shortage.

Although it is intended that this report should deal only with the material situation, the critical manpower shortage is having its effect in every phase of the industry.

Improved quality of materials. In general, the quality of materials available today are, for the most part, almost the equal of prewar materials. The use of national emergency steels has worked out fairly satisfactorily, but structural failures in some instances have caused costs as well as greater hazards in deeper drilling. Drilling bits have been inferior in quality due to the use of inferior grades of steel, however, there has been a pronounced improvement as of recent date. Probably due to the lack of tin in the alloy, sleeve type bearings for engines are also causing considerable trouble, resulting in too much shut-down time.

The search for new reserves is now largely directed to the drilling and completion of wells from 8000 to 15,000 ft. in depth. The drilling of these wells is taxing the strength of many parts of the rig to the absolute limit. If the trend to deeper drilling is continued, it will be necessary to have the best possible alloys with the highest strength and best wearing qualities in every part of a rotary rig.

Larger quantity of repair parts for stock. Probably the most serious handicap for the drilling contractor and operator is an inadequate supply of repair parts. Although the repair parts situation is somewhat improved, there are numerous instances where a rig has been shut down for as long as three weeks for a comparatively minor repair part. Under present conditions, the contractor must pay his crew during the shut-down period, with a resultant increase in overall costs. An adequate supply of repair parts will get more holes drilled per pound of steel expended than anything else that can be done. As a concrete illustration, there is the case of a wildcat well that came to our attention. This well was projected to a depth of 7000 ft. At 5000 ft. the crankshaft in one of the engines became worn beyond repair. Normally, repairs could have been accomplished in not to exceed 48 hr. Upon investigation, it was found it would require a minimum of 45 days to obtain a new shaft. Rather than lose the use of the rig for this period of time, the operator purchased a new engine. We are assured that this is by no means an unusual occurrence. Parts should be made available for distributor's stocks and every effort should be made to maintain these stocks at an adequate level. Failure to do this leads to the hoarding of parts by contractors and operators, thus reducing the availability of existing supplies and increasing the percentage of dead stock. The average drilling contractor probably has from one to five rigs, but is unable to foresee his material requirements far enough in advance to place orders for future delivery. It therefore falls back on the distributors and suppliers to carry an adequate stock.

In defense of the distributors and suppliers, it is well know that for the most part, they have carried all the stock allowed under government restrictions. These restrictions have recently been relaxed, however, further relaxation is an absolute necessity. In many instances, orders have been placed sufficiently in advance to care for properly current requirements, but it appears directives issued, which funnel supplies to other industries, have constantly forced the drilling industry into a position of secondary importance. We now understand these directives are to be less frequent.

A good example of an item that should be increased in the distributors' stocks is drilling bits. Ordinarily, a 45-day supply is allowed for the distributors. It requires at least 45 days to manufacture and deliver a bit from the raw material to the finished product, which results in little or no time factor as far as the industry is concerned. This has caused many contractors to use bits of a different type or size than those known to give the greatest drilling efficiency. An increased supply of this one item in distributors' stocks would result in an appreciable conservation of critical material.

Roller and ball bearings are some of the most difficult parts to obtain. We realize it would be quite a problem for every dealer to carry an ample stock, however, a central stocking point (probably one in each state) of all types of bearings would ease the situation to such an extent that the average contractor could obtain the items without too much delay.

Engine parts, such as carburetors, clutches, transmissions, magnetos and crank shafts, are all quite difficult to obtain. While this situation has shown some improvement, additional difficulties may be anticipated if the present rate of drilling continues unless stocks are further increased.

The supply of tool joints, drill pipe and drill collars still is short; however, the present manufacturing and consumption rates appear to be almost in balance.

The shortage of proper repair parts of all types and replacements is resulting in many operators and contractors using inferior equipment. They are fully aware of the risk, but there is no other alternative except to shut down. A survey discloses numerous fishing jobs directly attributable to this practice.

Better service facilities (repair and machine shop, transportation). Many machine and repair shops cannot make satisfactory repairs to parts due largely to unskilled help. More repair materials, such as shafts, castings, etc., should be available to machine shops under high priority order. Poor service from repaired parts is causing excessive trips on rigs and ultimately means less hole per day with a resultant greater wear and tear on the rig per foot of hole.

Machine shop owners should be permitted to obtain deferments on the more highly skilled machinists and welders. The scarcity of new repair parts has greatly increased the repairs of old wornout parts. Of course, a greater supply of new repair parts would ease the situation considerably.

The advent of deeper drilling naturally results in larger and heavier equipment. The transportation of this equipment is becoming increasingly difficult. A few contractors and operators have their own transportation equipment, however, a majority employ trucking contractors. Delays of as much as three weeks moving to a location are not uncommon. It is estimated that there has been a 300 per cent increase in moving time on rotary rigs. This is largely due to the shortage of repair parts for trucks and lack of experienced drivers. Some

*Presented before American Petroleum Institute, Mid-Continent Division of Production, Tulsa, Oklahoma, May 25-26, 1944.

†Chairman, A.P.I. Mid-Continent District Committee on Drilling Production.

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trucking contractors have had one-half of their equipment shut down due to one or both of the above mentioned causes. Surprisingly enough, trucking contractors have been able thus far to obtain sufficient gasoline and tires. There is a critical shortage of large tandem trucks and it is the consensus that the drilling rate will be seriously impaired unless sufficient new tandem trucks are released to the industry immediately.

There has been a considerable shortage of dirt moving equipment for digging ponds and pits. At the start of the war, a great many oil field dirt moving contractors obtained defense work; this resulted in a wholesale move of personnel and equipment from the oil fields. The release of new equipment as well as the return of these contractors from defense work will materially aid the industry.

Manpower shortage. The effect of the manpower shortage on the material situation cannot be overlooked. Reliably informed drilling contractors and operators estimate that on the average not more than 75 per cent total footage is being drilled per rig per day as before the war. Many draft boards take the position that roughnecks are neither essential nor critical workers, and although the industry has been able to retain experienced drillers, roughnecks are predominantly "4-F's" or over age. This has caused a general overall slow up and also an alarming increase in the accident rate, both as to frequency and severity. The rotary drilling industry is a young man's game particularly with respect to roughnecks. Draft boards should realize this and defer more experienced roughnecks as skilled oil field workers during the present emergency.

The shortage of housing facilities for drilling crews is rapidly becoming an important factor contributing to the critical manpower shortage. It has been suggested by some leaders in the industry that it might be possible to move idle trailer camps from completed defense projects to localities where housing facilities are known to be inadequate. With the high percentage of wildcat drilling now under way, trailer camps, due to their portability, might work out very satisfactorily.

Although there may be no immediate solution to the manpower situation in the industry, it definitely needs to be recnogized in any appraisal of the industry's need for additional and better equipment. The foregoing remarks are no more than a reiteration of facts widely known in the industry. However, the drilling industry must be recognized as a war activity and should receive profound consideration from the various control agencies. ★★★

Exports oil to Hitler

The United States is exporting oil to Germany in the form a 500-lb. block burner incendiary bomb, the U. S. War Department announced. The bomb contains a mixture of jellied oil and powdered magnesium. It is said that after the huge incendiary starts burning it cannot be put out.

New Calculator Determines Proper Size Transformer

P 062.

By V. W. PALEN*

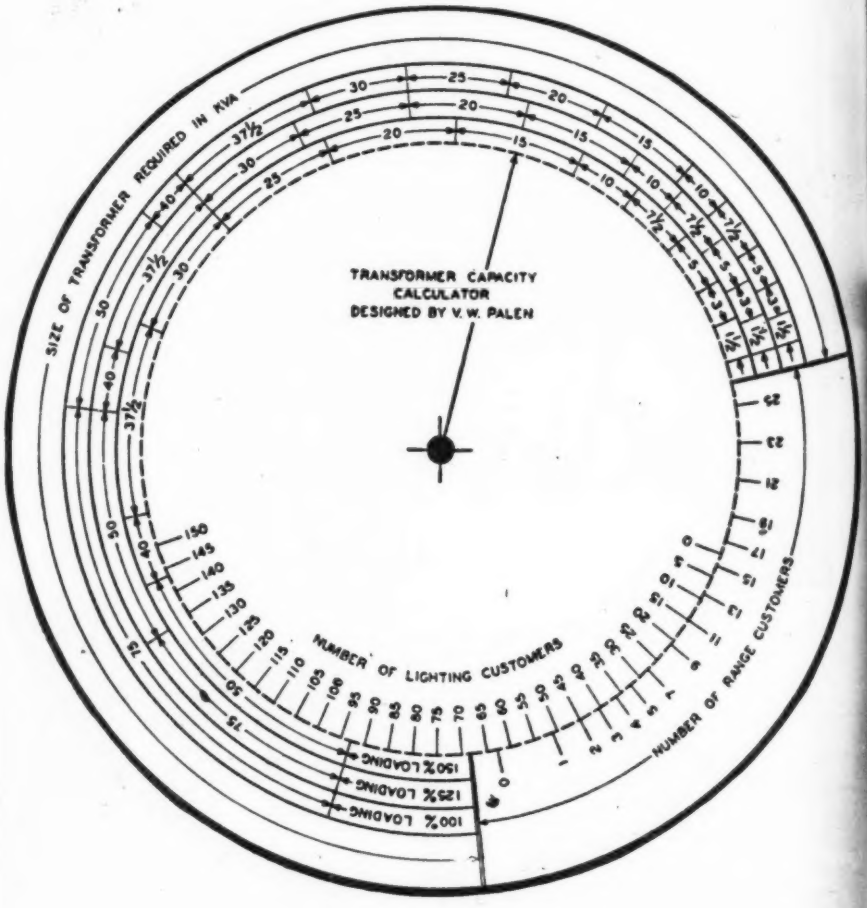
Routine problems are said to be simplified by this new time-saving device for engineers

IN LOCATIONS remote from utility company lines, construction and operation of a residential distribution system presents certain problems. The accompanying calculator quickly tells the engineer in charge of such work the proper size transformer to install for a given number of range and lighting customers. Likewise, it tells when a transformer should be replaced due to overload. Three loading scales (100, 125, and 150 per cent are shown on the periphery. Thus, if desired, transformers can be replaced when they reach 100 per cent of nameplate rating, or 125 or 150 per cent. As peak loads are rarely maintained for more than an hour or two, most engineers use the 150 per cent scale.

Suppose there are 13 range and 120 lighting customers—set the dial accordingly. Now note that the arrow calls for a 37½-kva. transformer on the 150 per cent scale. Lighting demands are assumed to be 300 watts per customer. Range demands vary according to a hyperbolic curve—3.6 kw. for one range, decreasing to approximately 1.1 kw. per range for 21 or more units.

Certain transformer sizes that are no longer manufactured (20, 30, and 40 kva.) are included on the calculator for the convenience of those companies still having them in use.

To assemble the calculator, cut along the inner and outer circles to make a ring and a disk. Mount these pieces on separate pieces of cardboard using rubber cement. Punch the center hole carefully. Insert a brass bolt (with washers) to hold the parts together. Add a nut to the bolt and tighten—the disks should turn easily yet hold their setting. A drop of solder on the nut makes the assembly permanent. ★★★



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ENGINEERING AND CONSTRUCTION OF SANTA MARIA VALLEY PLANT†

By D. E. McFADDIN*

THE Santa Maria Valley oil field was discovered by the Union Oil Company of California in 1934. The oil from this field is heavy, running about 15 deg. A.P.I. gravity and has a high sulphur content. During the first 3 years of the life of the field there was virtually no demand for oil of this character and production was at a minimum; however, with the coming of World War II the demand increased so that now there is urgent demand for the maximum of oil production. The conservation and proper utilization of the gas associated with the increased oil production has consequently required the installation of gas treating and handling facilities.

D. E. McFaddin

In 1937, gas equipment was installed in the Santa Maria Valley field to compress about 5,000,000 cu. ft. per day of wet gas from 20 lb. gauge to about 150 lb., and to remove the hydrogen sulphide content of the gas by means of an iron oxide bed and then to transport the gas through 7 miles of 6-in. pipe to Union Oil Company's Orcutt absorption plant, where facilities were available to recover the gasoline content of the gas and to deliver the surplus dry gas into the Southern Counties Gas Company lines. This operation was satisfactory for several years, but by the early part of 1942 production had increased until it was apparent that a complete absorption plant was needed in the Santa Maria Valley. It will be remembered that at this time very little new material was available for constructing an absorption plant, and it was necessary to comb the country for idle used equipment. Table 1 lists the major units of equipment and indicates their source. It is seen that nearly all major units were obtained from idle equipment that had previously been in service many years. All equipment was thoroughly reconditioned in the Union Oil Company salvage shops at Santa Fe Springs. In some cases, 15-year-old "bare rod" welding on pressure vessels was found to have a tensile strength insufficient to meet the desired working pressure. This bare rod welding was chipped out and the vessels rewelded according to modern standards. Pumps, safety valves, and instruments also were a very difficult problem and many items of this class were rebuilt in Union Oil Company shops from equipment that had long been discarded. Engineering and process and construction of a plant with such a limited availability of equipment presented many unusual problems. Nevertheless, with help from the War Production Board District 5 office, the necessary priorities were obtained and construction was begun on April 15, 1943, and the plant was completed and put into operation Dec. 30.

TABLE 1

Source and description of the main units of the Santa Maria Valley absorption plant

Compressors

One 150 hp. model XVG Ingersoll Rand compressor, 350 r.p.m.

One low stage cylinder 12 in. x 14 in. with variable clearance.

One high stage cylinder 8 in. x 14 in.

Eleven Cooper Type 80 twin compressors, 200 r.p.m.

One low stage cylinder 13 in. x 20 in. with clearance chambers.

One high stage cylinder 8 in. x 20 in.

The Coopers were fitted with special cams to enable developing the maximum horsepower.

The Cooper power cylinders were also adapted to overhead air intakes and were equipped with Vortox air cleaners.

The Ingersoll Rand XVG and three of the Cooper 80's had been installed at the plant location prior to the construction of the absorption plant in 1943.

All additional compressors had previously been in service at various locations many years and required extensive repair work before being put into service in the new plant. The Coopers are now developing about 185 b.hp.; and were originally rated by the manufacturer at 175 b.hp.

Absorbers

Two 46 in. I.D. by 25 ft. high absorbers, previously used in a North Belridge absorption plant, were adapted for use at Santa Maria. These vessels had been operated at 400 lb. gauge for many years, but under present code standards they are rated at 200 lb. gauge maximum allowable working pressure.

Each absorber has a computed maximum capacity of about 11,000,000 cu. ft. per day at 200 lb. gauge with an oil circulation of 8000 gal. per hr. In order to obtain this capacity the total number of perforations in each tray was increased from 1900 to 5700 and new larger inlet and outlet nozzles were installed. The perforations are 9/64 in. in diam. Each absorber originally had 16 trays; however, it was necessary to sacrifice one tray in each absorber to accommodate the new nozzles.

Interchangers

Six Braun K-155 units with a total heat transfer surface of 2200 sq. ft. were obtained from a dismantled absorption plant at Elwood. They were installed in two parallel banks, each with three units in series. A heat transfer K of 100 B.t.u. per sq. ft. per °F. temperature difference is being obtained with these units, which is very good performance.

Rich Oil Fractionator

A 32 in. I.D. by 50 ft. high column with 22 bubble cap trays was obtained for this service. It was formerly used as a stabilizer column in an Elwood absorption plant and originally had a maximum allowable working pressure of 250 lb. gauge; however, this was reduced to 170 lb. gauge in accordance with present safety code standards.

Preheaters

Two Braun F 150 units with a total heat transfer surface of 750 sq. ft. were obtained from a dismantled plant at Elwood. These units are now performing with a heat transfer "K" of over 200 B.t.u. per sq. ft. per °F.

Fractionating-Stripping Still

A 60 in. I.D. by 55 ft. high column with 19 perforated trays was obtained from Union Oil Company's Bell absorption plant at Santa Fe Springs where it had been standing idle for about 10 years. It has a 55 lb. maximum allowable working pressure; built in oil reheaters, and facilities to withdraw stripping steam condensed within the fractionating section of the column. The perforations of the fractionating trays for this column had previously been drilled beyond the limit of efficient performance for the conditions at the Santa Maria absorption plant. Therefore about 50 per cent of the perforations were blanked off with plates of sheet metal. They are performing satisfactorily.

Stabilizer

A 32 in. I.D. by 77 ft. high column with 40 bubble cap trays, together with interchangers and a reboiler, were obtained from Union Oil Company's absorption plant at Del Rey, where they were standing idle. They had been in corrosive service for about 12 years; however, after some repair work, a maximum allowable working pressure of 230 lb. was obtained, which is only 20 lb. less than the 250 lb. working pressure allowed when the vessel was first built.

This vessel was originally equipped with a reflux condenser located on its top. This part of the equipment was in bad condition and was junked. The unit was then redesigned to operate with a reflux tank at ground level with condenser coils located in a cooling tower. The reboiler was also redesigned and augmented. Side draw-off connections were provided between the feed inlet and column top for the production of an isobutane cut or of liquefied petroleum gas.

Oil Conditioner

A 20 in. diam. oil conditioner was constructed entirely from salvaged material to separate gums and foreign matter from the oil.

▼ **Plant design.** The Santa Maria Valley absorption plant was designed to process a maximum of 18,000,000 cu. ft. per day with an absorption oil circulation of 16,000 gal. per hr. and an absorber pressure of 190 lb. gauge; extracting 80 per cent of the isobutane content, 97.5 per cent of the normal butane, and 99.2 per cent of the pentanes and heavier content of the gas. Table 2 gives the overall plant commodity balance. The gas from the field reaches the plant at approximately 23 lb. gauge, and is compressed to 210 lb. in two stages. At the interstage pressure of about 75 lb. the gas is countercurrently contacted with 4 per cent soda ash solution to remove the major portion of the hydrogen sulphide. The remainder of the hydrogen sulphide is removed by iron oxide beds after the gas has been compressed to 210 lb. The isobutane and heavier fractions of the gas are then extracted from the gas by absorption oil circulated through absorbers operating at about 190 lb. The water vapor content of the absorption plant discharge gas is then removed in a Southern Counties Gas Company gas dehydration plant, employing diethylene glycol, in order to prevent subsequent condensation and corrosion in the gas company's fuel gas transportation and distribution system. A large part of the plant discharge gas is utilized in the Santa Maria Valley area for domestic and industrial purposes. The remainder is transported to Union's Orcutt compression plant where it is compressed to 400 lb. and delivered into the Southern Counties Gas Company's main lines to Santa Barbara.

Fig. 1, the flow chart, shows that the absorption plant cycle is quite simple.

†Before C.N.G.A., July, 1944.

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There are two absorbers. Each is 46 in. I.D. and 24 ft. high and contains 15 perforated trays. The absorption oil is metered to the top of each absorber and flows from tray to tray downward, countercurrently against the rising gas. Liquid level controllers automatically hold a constant oil level in the bottom section of each absorber. The main stream of enriched oil from the bottoms of the absorbers flows through interchangers where it is heated to approximately 290° F. It then flows into a rich oil fractionator at 100-lb. pressure. This unit is installed to separate the major portion of the methane and ethane from the absorption oil and other absorbed fractions. The gasoline content of the plant intake gas from the Santa Maria Valley oil field is unusually low. This fact has a direct bearing on the condensation and separation of the gasoline and isobutane and propane from the lighter absorbed fractions.

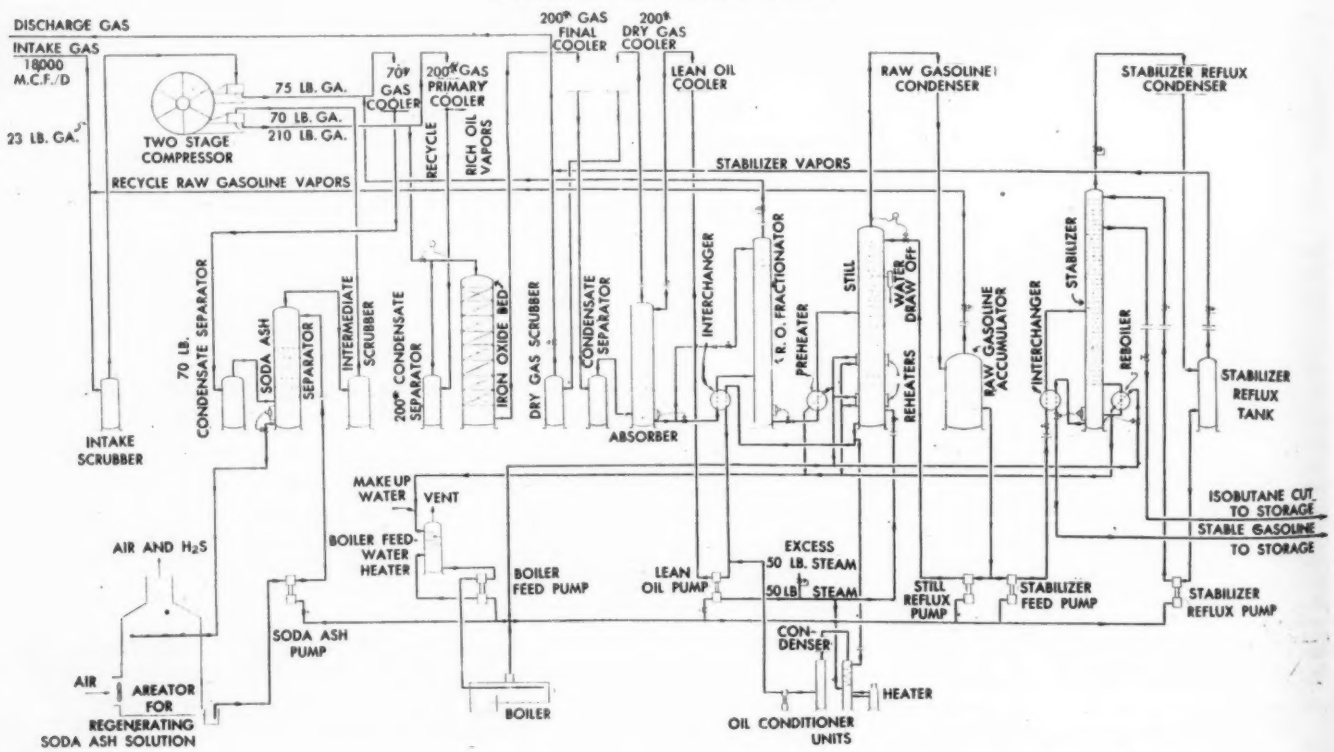
When theoretical computations were made to determine the proper process cycled it was found that either a high pressure (100 lb.) still, a rich oil fractionator, or some other facility was required that would eliminate the major portion of the methane and ethane from the cycle before the main (40 lb.) raw gasoline condenser was reached. Otherwise these light fractions would prevent the satisfactory condensation of the other fractions, especially of propane and the butanes. The use of a 32-in. I.D. rich oil fractionator was found to be best suited to the present requirements at the Santa Maria Valley plant. The rich oil and vapor from the interchangers at 290°F. enters the bottom section of the column where the liquid is separated from the vapor. The liquid flows out the bottom to the preheaters while the vapor rises upward through fractionating trays countercurrently against a stream of cold rich oil that flows direct from the 190-lb. absorbers to the top of the rich oil fractionator. Table 3 gives the analy-

TABLE 2
Overall plant commodity balance, Santa Maria Valley absorption plant

Component	18,000,000 cu. ft. per day intake gas			Extracted products				17,280,000 cu. ft. per day discharge gas		
	Gas volume, per cent	Gal. per M. cu. ft.	Gal. per day	29-lb. RVP gasoline, gal. per day	Isobutane side cut, gal. per day	Total liquids, gal. per day	Liquid extraction, per cent	Gas volume, per cent	Gal. per M. cu. ft.	Gal. per day
Hydrogen sulphide	25 gr./100 c.f.							0.00		
Water vapor	0.30							0.05		
Air	1.00							1.00		
Carbon dioxide	8.80							9.20		
Methane	79.83				10	10		83.10		
Ethane	3.87				25	25		4.02		
Propane	3.19				1120	1120		2.48		
Isobutane	0.51	0.167	3006	240	2166	2406	80	0.11	0.035	600
N-butane	1.22	0.383	6894	6200	524	6724	97.5	0.03	0.01	170
Pentane and heavier	1.28	0.500	9000	8930		8930	99.2	0.01	0.004	70
Total	100.00			15,370	3845	19,215		100.00		

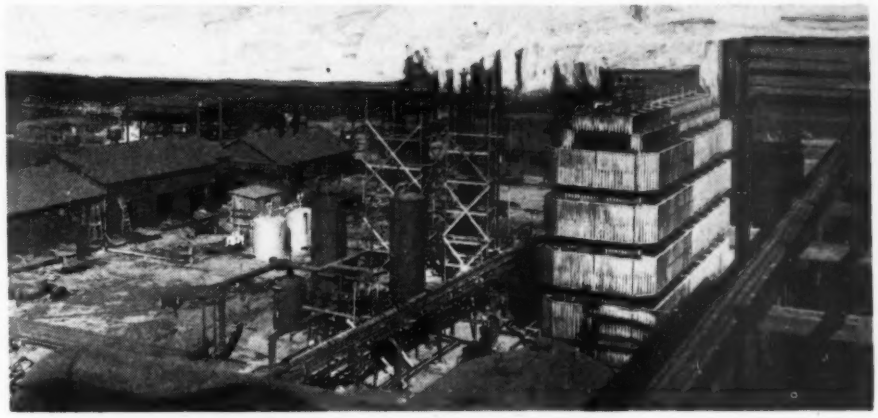
Cooling towers at the absorption plant.

PROCESS FLOW DIAGRAM
SANTA MARIA VALLEY ABSORPTION PLANT



ses and rates of the rich oil fractionator vapor and the raw gasoline accumulator vapor. From these analyses it is computed that 86 per cent of the methane and 71 per cent of the ethane are removed from the system by the rich oil fractionator.

The vapor from the top of the rich oil fractionator is commingled with the interstage untreated gas at 70-lb. pressure and is compressed and recycled through the absorbers. A heater, condenser, accumulator, and pumps are not required for this unit and its operation is very simple. At some future date it can be readily converted to a pressure still in order to produce propane liquid, by installing a 100-lb. condenser and accumulator. In that case, a small portion of the raw gasoline production from the low pressure stripping still would be used as reflux for the high pressure still and the remainder of the raw gasoline production from the low pressure stripping still would be circulated through the 100-lb. pressure condenser to serve as an absorbing medium for the desired propane. The stabilizer would then be fed from the 100-lb. accumulator.



Two views of new plant of Union Oil Company of California.

The rich oil from the bottom of the rich oil fractionator flows through steam heated preheaters into the main stripping and fractionating still where the raw gasoline fractions are removed from the absorption oil. The fractionating-stripping still is 60 in. in diam. by 55 ft. high. It has 19 perforated trays, 13 of which are above the feed inlet. A water draw-off tray is situated immediately below the seventh tray from the top, leaving 6 trays between the feed inlet and the water draw-off tray.

The still also has built in oil reheaters situated below the feed inlet. One is between the second and third tray from the bottom and another is situated below the bottom tray. It was realized that the heaters in this still are not ideally located, the optimum location being about two trays down from the feed; however, the cost of changing the location of the heaters would have been prohibitive and it was therefore decided to use the still "as-is."

Exhaust steam at 50 lb. gauge from the lean oil pumps is metered into the bottom section of still and rises upward through the perforations of the trays in order to strip all raw gasoline fractions from the oil. The still operates at 45 lb. gauge with a bottom temperature of 350°F. and a top temperature of 170°F. The top temperature is maintained automatically by a temperature controller that regulates the amount of raw or stable gasoline used as reflux to the top of the still. The bottom section of the still provides surge capacity for the system and the level at this point varies according to the amount of oil in the system.

The hot lean oil from the bottom of the fractionating-stripping still flows through the shell side of the interchangers to the lean oil pumps, which raise the pressure to 250 lb. so that it will flow through the lean oil coolers and into the absorbers, thereby completing the oil cycle.

The raw gasoline production together with the still reflux leaves the top of the still in vapor form and is then condensed in cooling units placed in the cooling tower and finally is accumulated as a liquid in the raw gasoline surge tank at 40 lb. gauge and about 65°F. The raw gasoline production is then pumped into the stabilizer at 200 lb. where the normal butane and heavier fractions are separated from the remainder of the raw gasoline by fractionation and are produced as stabilized gasoline from the bottom of the column. This product at Santa Maria has a Reid vapor pressure of about 30 lb. at 100°F. The isobutane content of the raw gasoline is required by alkylation plants in the refineries for the production of aviation gasoline. It is therefore produced as a liquid along with some normal butane and propane as a side cut from the column. This side cut liquid is withdrawn from about the sixth tray from the top of the column. It is impossible to produce a pure isobutane in this manner because a side cut must contain at least a limited amount of all the lighter fractions that appear overhead. A satisfactory concentration of the desired product can often be obtained in this manner, however.

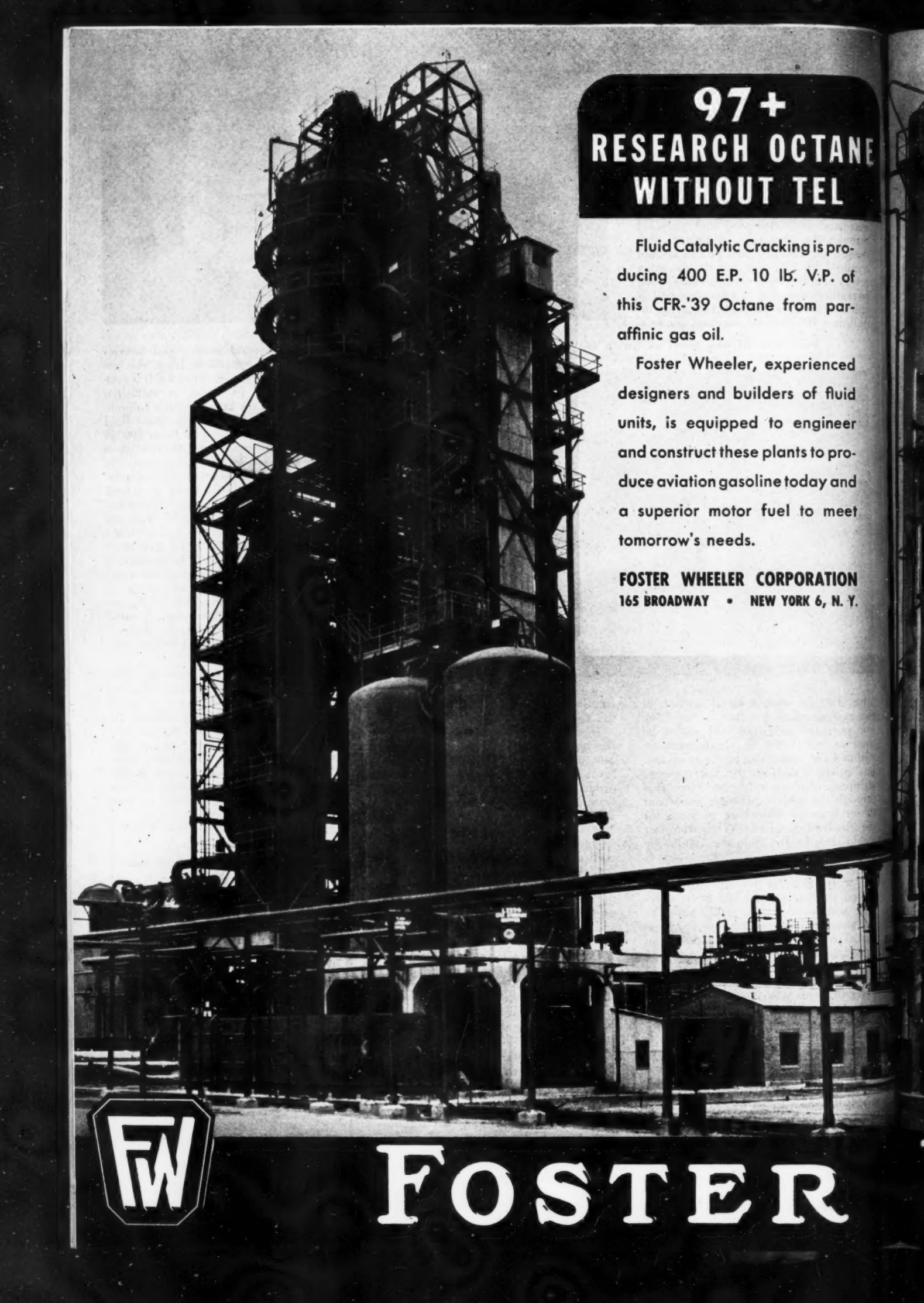
▼ **Hydrogen sulphide removal.** The removal of hydrogen sulphide from the Santa Maria gas constitutes a major problem. The hydrogen sulphide can be completely removed by means of iron oxide beds, which convert the hydrogen sulphide to ferric sulphide; then oxygen, which must be present in the gas for this process to function, converts the ferric sulphide back to iron

(Continued on Page 198)

TABLE 3

Recycled vapors, Santa Maria Valley absorption plant

	Rich oil fractionator vapors	Raw gasoline accumulator vapors
Analysis	Mol per cent	Mol per cent
Water vapor	0.50	0.50
Carbon dioxide	12.60	5.80
Methane	49.64	17.50
Ethane	12.64	11.23
Propane	20.72	36.13
Isobutane	1.40	9.38
N-butane	1.93	15.75
Pentanes and heavier	0.57	3.71
	100.00	100.00
Gallonage Content	Gal. per M. cu. ft.	Gal. per M. cu. ft.
Isobutane	0.456	3.055
N-butane	0.607	4.954
Pentanes and heavier	0.207	1.349
Gas rate, M. cu. ft. per day	610	280
Recycled Gallonage	Gal. per day	Gal. per day
Isobutane	278	855
N-butane	370	1390
Pentanes and heavier	126	378



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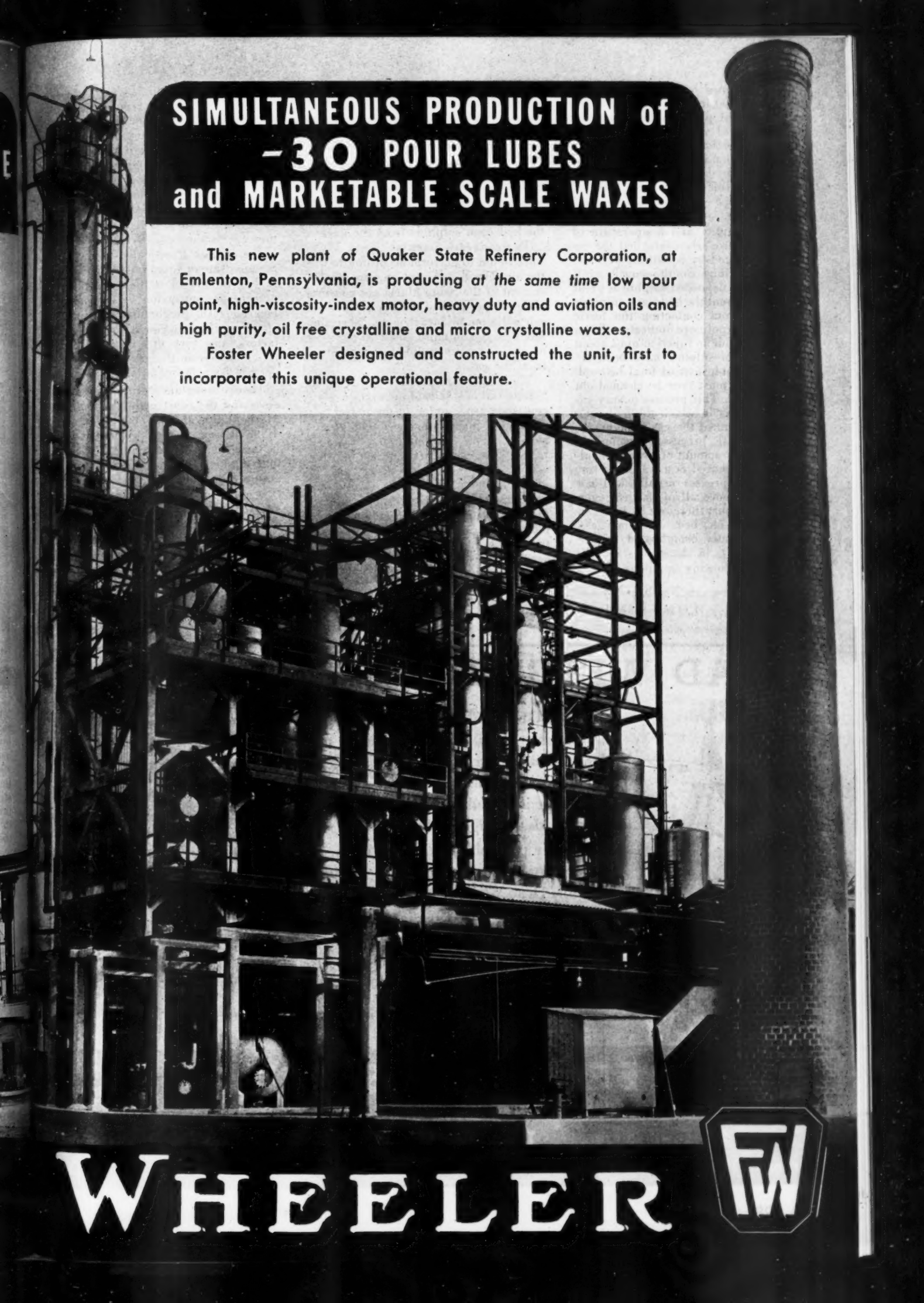
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(Continued from Page 195)

oxide and deposits free sulphide in the bed. In actual practice the iron oxide bed consists of wood shavings impregnated with ferric oxide, thus leaving a large proportion of the bed volume void to receive the deposited sulphur. The equations for this process are as follows:

$$Fe_2O_3 + 3H_2S \rightarrow Fe_2S_3 + 3H_2O \quad . \quad (1)$$

$$2Fe_2S_3 + 3O_2 \rightarrow 2Fe_2O_3 + 6S \quad . \quad . \quad . \quad (2)$$

If the humidity and temperature of the gas are properly controlled the reactions indicated by equations (1) and (2) will continue simultaneously until the amount of deposited sulphur is great enough to prevent the hydrogen sulphide in the gas from contacting the ferric oxide. Past experience indicates that a bed will continue to function until about 20 to 25 lb. of sulphur have been deposited per cubic foot of total bed volume. The bed must then be cleaned out and recharged. This process is very expensive in cases in which the hydrogen sulphide content of the gas is high.

The soda ash process is commonly used where the amount of hydrogen sulphide to be removed is great; however, the soda ash process usually will not completely remove all of the hydrogen sulphide and must therefore be followed by an iron oxide bed. The soda ash process is greatly complicated by the presence of CO_2 in the gas as is indicated by the following equations.

$$Na_2CO_3 + H_2S \rightarrow NaHS + NaHCO_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$Na_2CO_3 + CO_2 + H_2O \rightarrow 2NaHCO_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

These reactions are reversible and according to the law of mass action a high carbon dioxide content of the gas causes a high sodium bicarbonate concentration as indicated by equation (2), moving from left to right. The high sodium bicarbonate concentration resulting from equation (2) shifts the reaction equilibrium of equation (1) from right to left, thereby reducing the removal of the hydrogen sulphide from the gas.

The soda ash units at Santa Maria were found to perform according to this theory. The 8 per cent carbon dioxide content of the Santa Maria gas converts about 99 per cent of the 4 per cent soda ash solution to bicarbonate. Nevertheless with this mixture about 70 per cent of the hydrogen sulphide is removed from the gas.

The soda ash process provided at Santa Maria consists of pumping a 4 per cent soda ash solution to the top of two parallel 81-inch diam. contractors or absorbers, each containing 6 perforated trays. The contactors operate on the cooled compressor interstage gas at about 70 lb. gauge, and a solution-to-gas ratio of about 35 gal. per standard M. cu. ft. is employed. The solution from the bottom of the contractors flows through liquid level controllers to an aerator where equation (1) is reversed by spraying the solution into a rising current of air, so as to remove the hydrogen sulphide from the field of action and discharge it from the top of the aerator. A conventional forced draft cooling tower with a 50 ft. high extended discharge stack is employed as the aerator and sufficient air is blown through the aerator to dilute the hydrogen sulphide to below the toxic danger limit. Equation (2) is theoretically also reversible in the aerator. Practically, however, the reaction rate of equation (2) from right to left is very slow. Consequently the percentage conversion of carbonate to bicarbonate is predominately a function of the equilibrium conditions in the contactors, and very little carbon dioxide is removed from the gas after the process has been in operation a short time.

There are certain features of the processes and the construction of the Santa Maria Valley absorption plant that are different from an ideal plant that would be constructed if the required materials and equipment are available. For example, direct fired heat of the absorption oil is superior to steam heat. Also, absorbers with 20 or more trays instead of 15 trays are advantageous. Despite these limitations, however, the fact remains that the plant was successfully constructed and put into operation under adverse conditions and is adding its share of production to the war effort.

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By GARTH F. NICHOLSON and M. B. RIORDAN

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G. F. NICHOLSON

M. B. RIORDAN

Garth F. Nicholson was graduated from California Institute of Technology as a B.S. in M.E. in 1934. He was made Chief Engineer, Oil Tool Division of Byron-Jackson in 1942.

M. B. Riordan won the degree of B.S. in Chemical Engineering from Southern California, 1939. He joined Byron-Jackson in 1939 and was appointed Chief Metallurgist in 1943.

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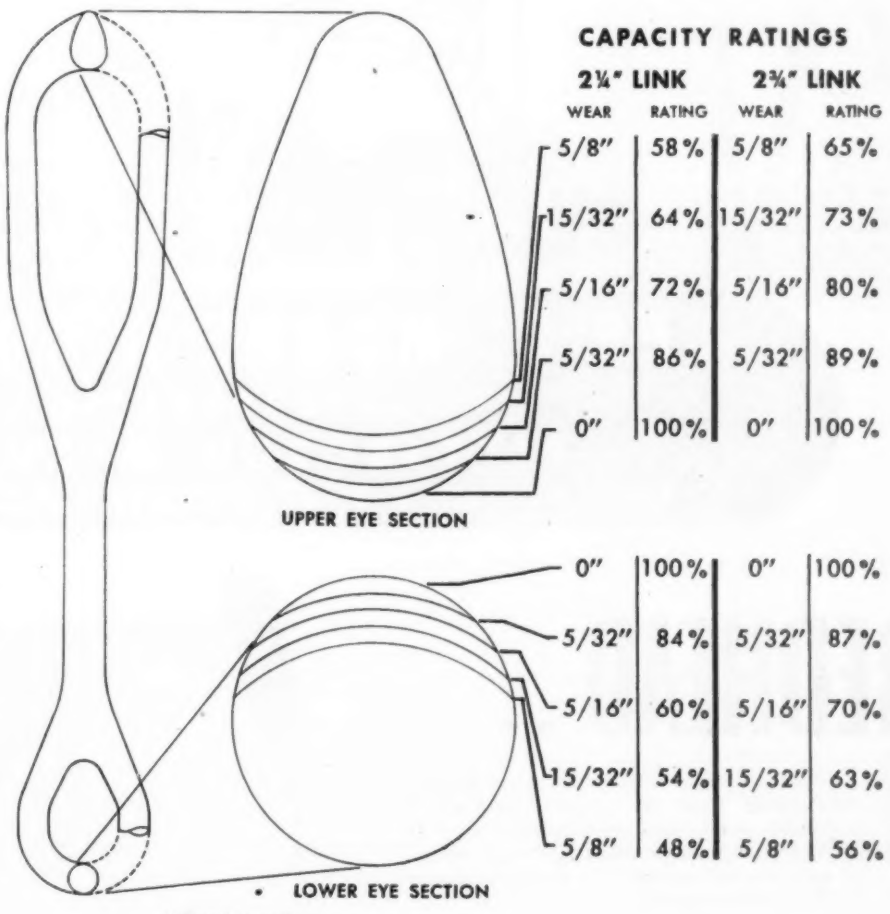

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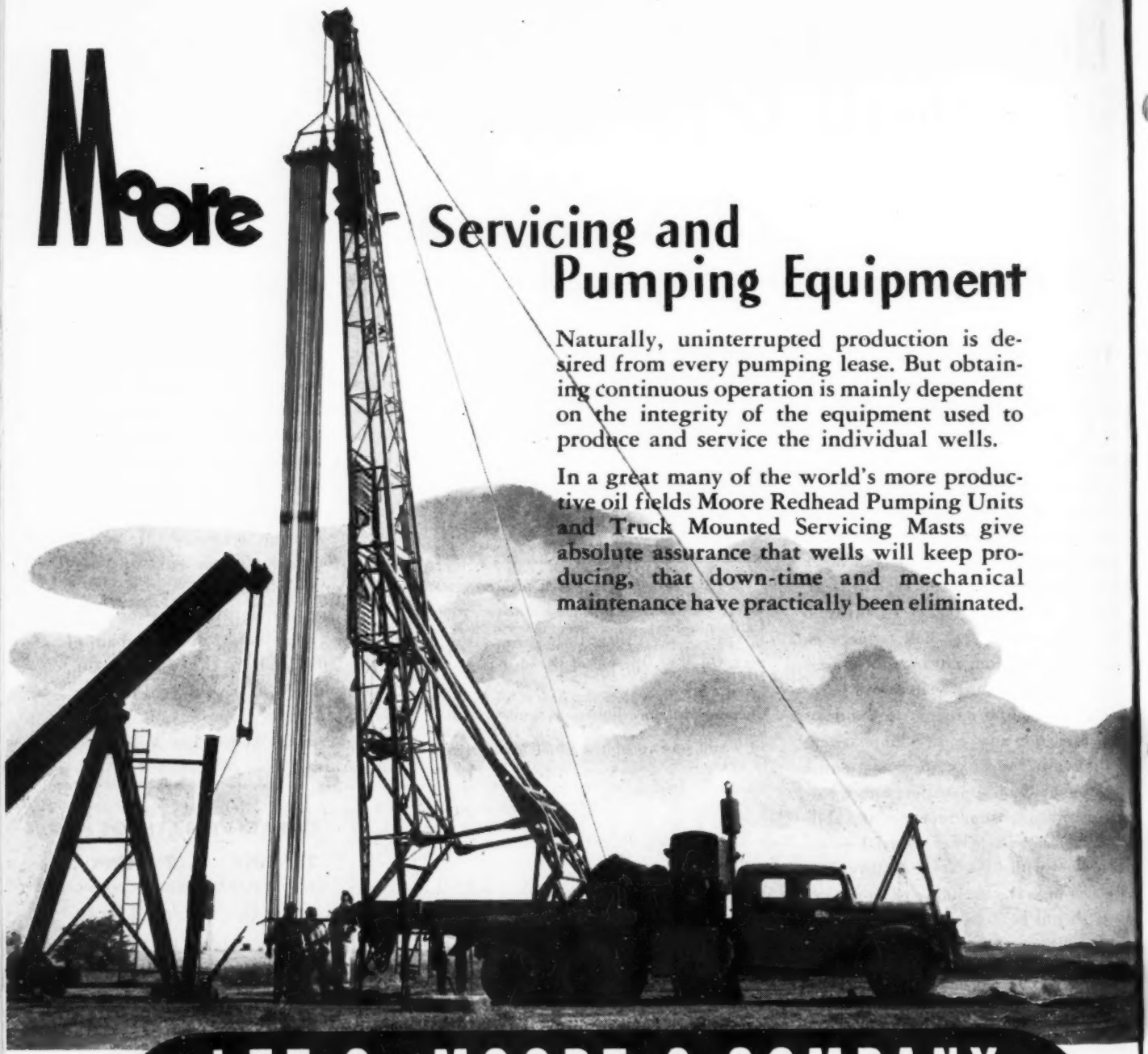

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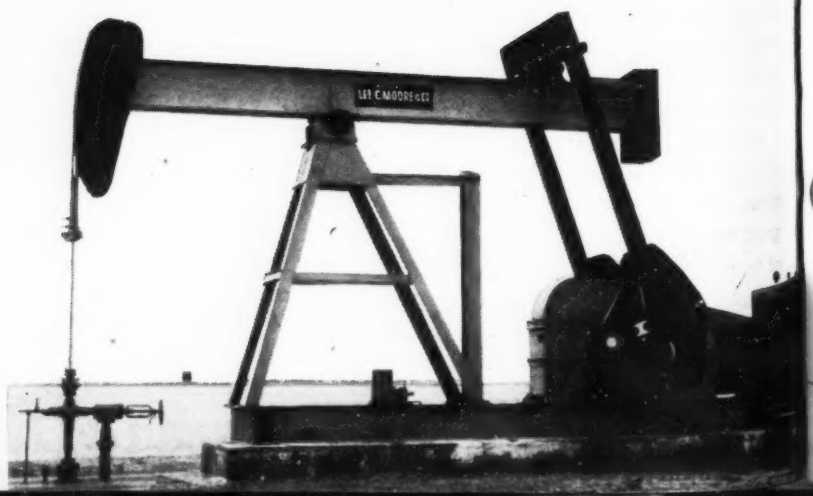

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The Continuous Tables have developed as a result of suggestions for new tables, direct contributions, and improvements to existing tables by members of the petroleum and related industries, including manufacturing concerns, who are continually searching for practical information reduced by computation to tabular form readily applicable to the problems daily confronting them that might otherwise necessitate a more or less tedious calculation. These contributions and suggestions from the industry have resulted in a valuable exchange of information and data contributing to the progress of the industry as a whole.

This index will be revised monthly. The index for installments 1-12, inclusive, will be found in the May, 1938, issue; 13-24, inclusive, in the June, 1939, issue; 25-36, inclusive, in the June, 1940, issue; 37-48, inclusive, in the June, 1941, issue; 48-60, inclusive, in the June, 1942, issue; 61-72, inclusive, in the June, 1943, issue, 73-79, inclusive, in the January, 1944, issue, 80-82, inclusive, in the April, 1944, issue, and 83-85, inclusive, in the July, 1944, issue.

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Hazard Wire Rope Division of American Chain & Cable Co., Inc.	(sheet 5)	208	Aug.	P 514.535.
Hyatt Bearings Division, General Motors Sales Corporation	(sheet 4)	206	Aug.	P 514.535.
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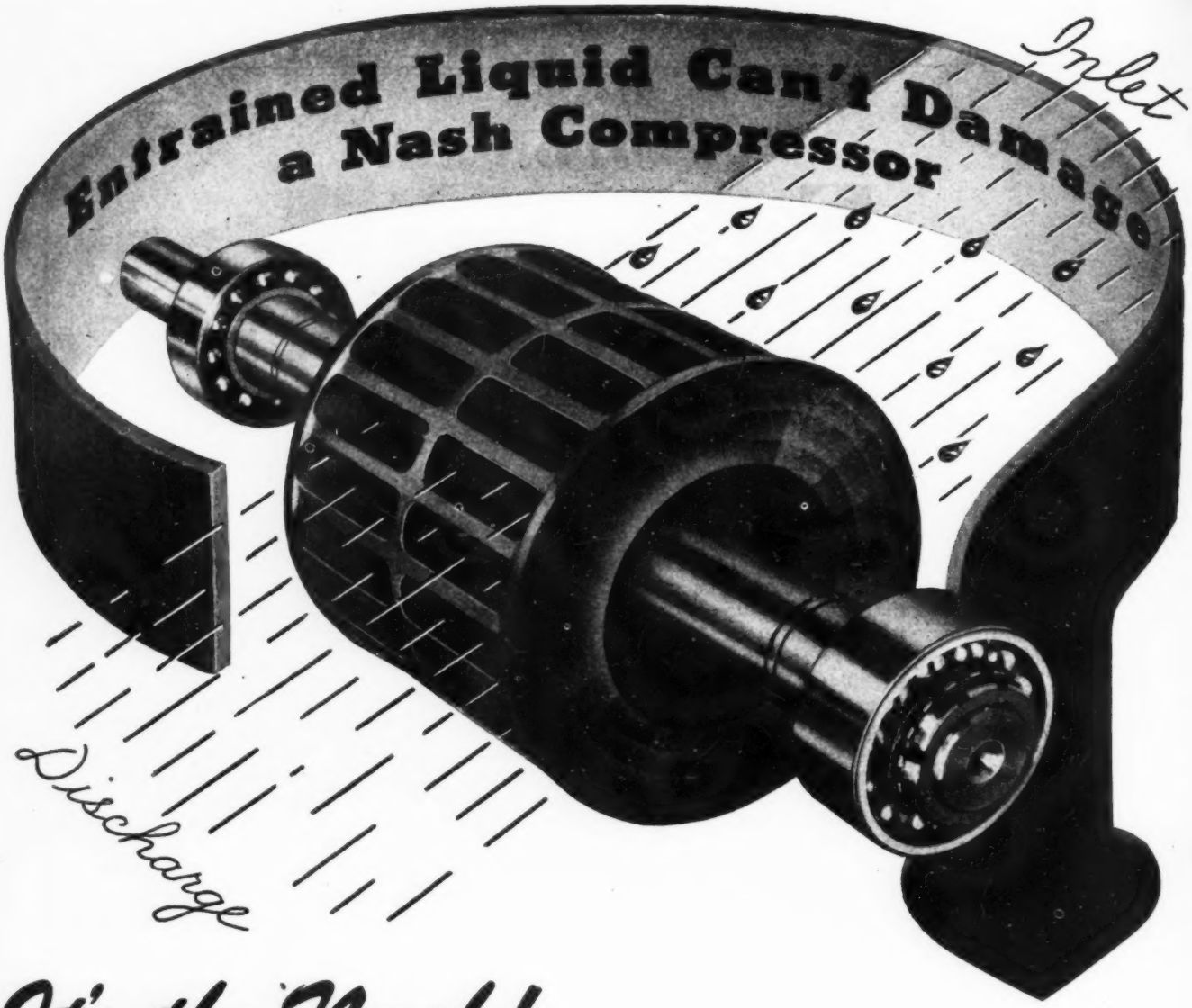
Torrington Company, Bantam Bearings Division	(sheet 6)	214	Aug.	P 514.535.

Entrained Liquid Can't Damage a Nash Compressor



It's the Nash!

The ability of Nash Compressors to maintain original performance thruout a long life is only one of the many advantages which derive from the Nash liquid piston principle of compression.

Since this liquid piston is an integral part of the Nash Compressor, additional liquid can do no harm to the pump structure, whether in the form of slugs entering by accident, or as condensate forming in the suction lines. In handling gases, for example, wet hydrocarbons, usual elaborate protective devices are eliminated. The hazards of such devices are therefore avoided, the cost of installation is saved, and freedom from repairs and shutdowns is assured.

Nash Compressors produce 75 lbs. pressure, or vacuums to 26 in. of mercury, in a single stage, with capacities to 6 million cubic feet per day in a single structure. They have but one internal moving part, simple and non-wearing. There are no valves, gears, pistons, sliding vanes, or other enemies of long life. No gas contaminating internal lubricant is employed. Compression is without pulsation. It will be to your advantage to investigate the Nash Compressor.

26 in. mercury vacuum or 75 lbs. pressure in one stage.

No internal wearing parts.

No internal lubrication to contaminate gas handled.

Desired delivery temperature automatically maintained.

Non-pulsating pressure.

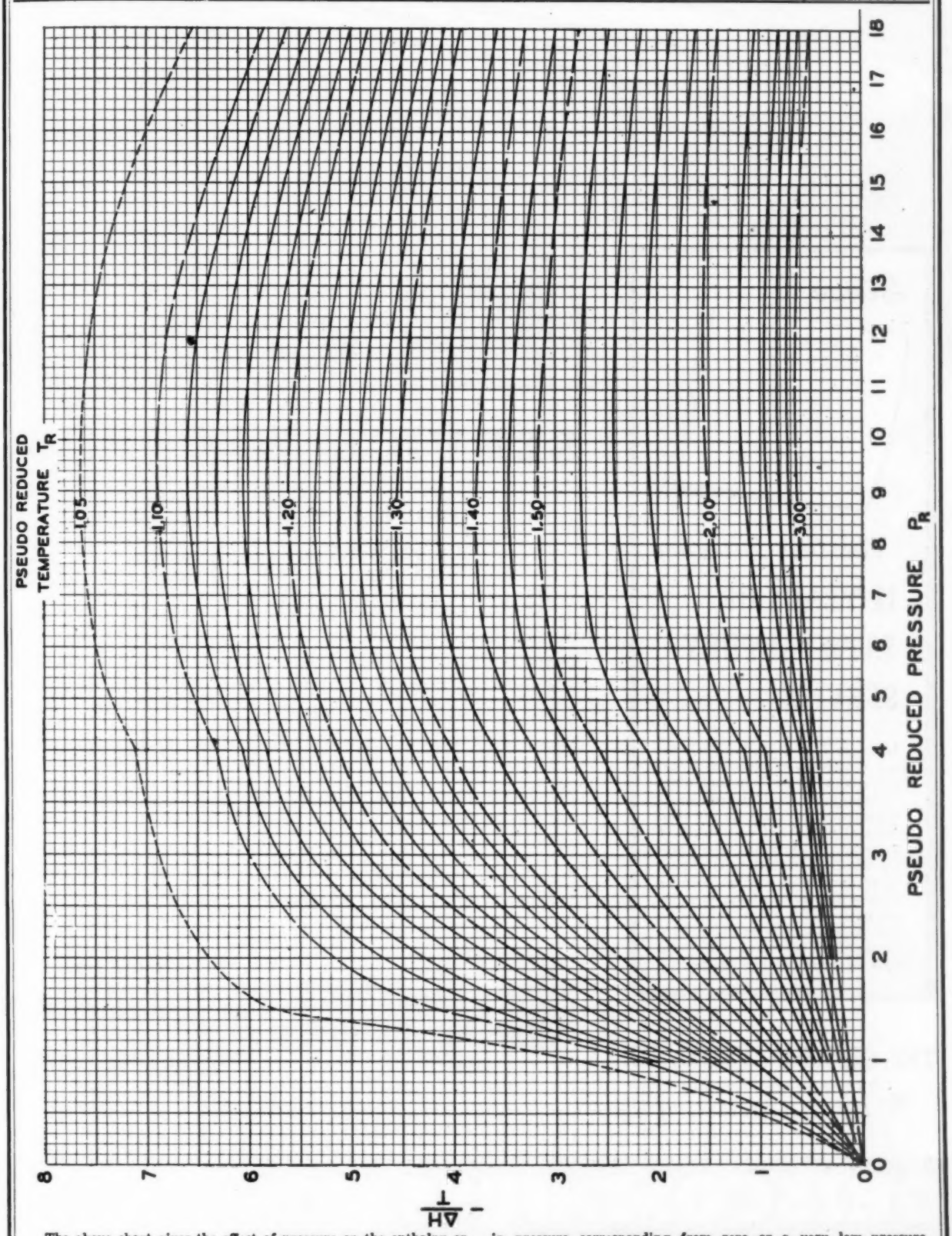
Original performance corstant over a long pump life.

Low maintenance cost.

NASH ENGINEERING COMPANY

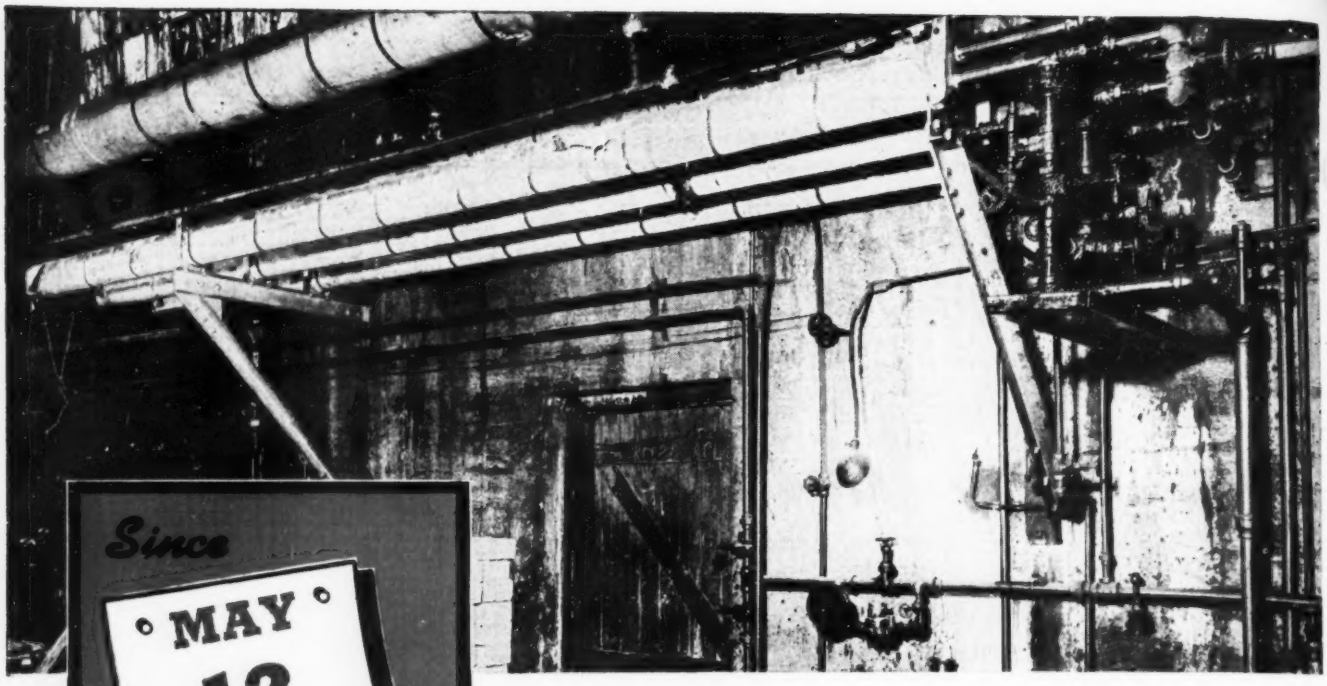
286 WILSON, SO. NORWALK, CONN.

PRESSURE EFFECT ON ENTHALPY OF NATURAL GAS, CONSTANT TEMPERATURE



The above chart gives the effect of pressure on the enthalpy or heat content of a natural gas at constant temperature. The decrease in enthalpy may be obtained by multiplying the value on the ordinate (—H/T) by the absolute temperature for an increase in pressure corresponding from zero or a very low pressure where the vapor is substantially an ideal gas, to the pressure corresponding to the pseudo reduced pressure indicated along the abscissa.

—Chart by George Granger Brown, University of Michigan.



Since

° MAY °
12
1933

Another Instance

11 YEARS OF SATISFACTORY SERVICE

The three Twin G-Fin Sections illustrated above were installed as fuel oil heaters in an industrial plant in May 1933, and are still operating with complete satisfaction. Some of the special advantages of Twin G-Fin Sections are their superior effectiveness in transfer of heat to or from fluids of high viscosity or low heat conductivity, their interchangeability which promotes flexible capacity, and their compactness and lightness which assists ease of handling and erection.

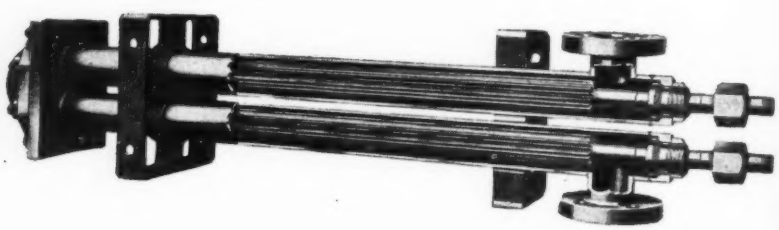
SERVICE RECORDS

prove the excellence of G-FIN construction

G-Fin . . . the extended heat transfer surface with longitudinal fins originated by Griscom-Russell more than 12 years ago . . . has PROVEN its durability, as well as its effectiveness, through the operating records of more than 40,000 installed units in which G-Fin elements are used.

Moreover, the excellence of G-Fin design and construction is further proven by an unequalled range of successful applications, for G-Fin units are being used on a greater variety of services than any other heat transfer apparatus on the market.

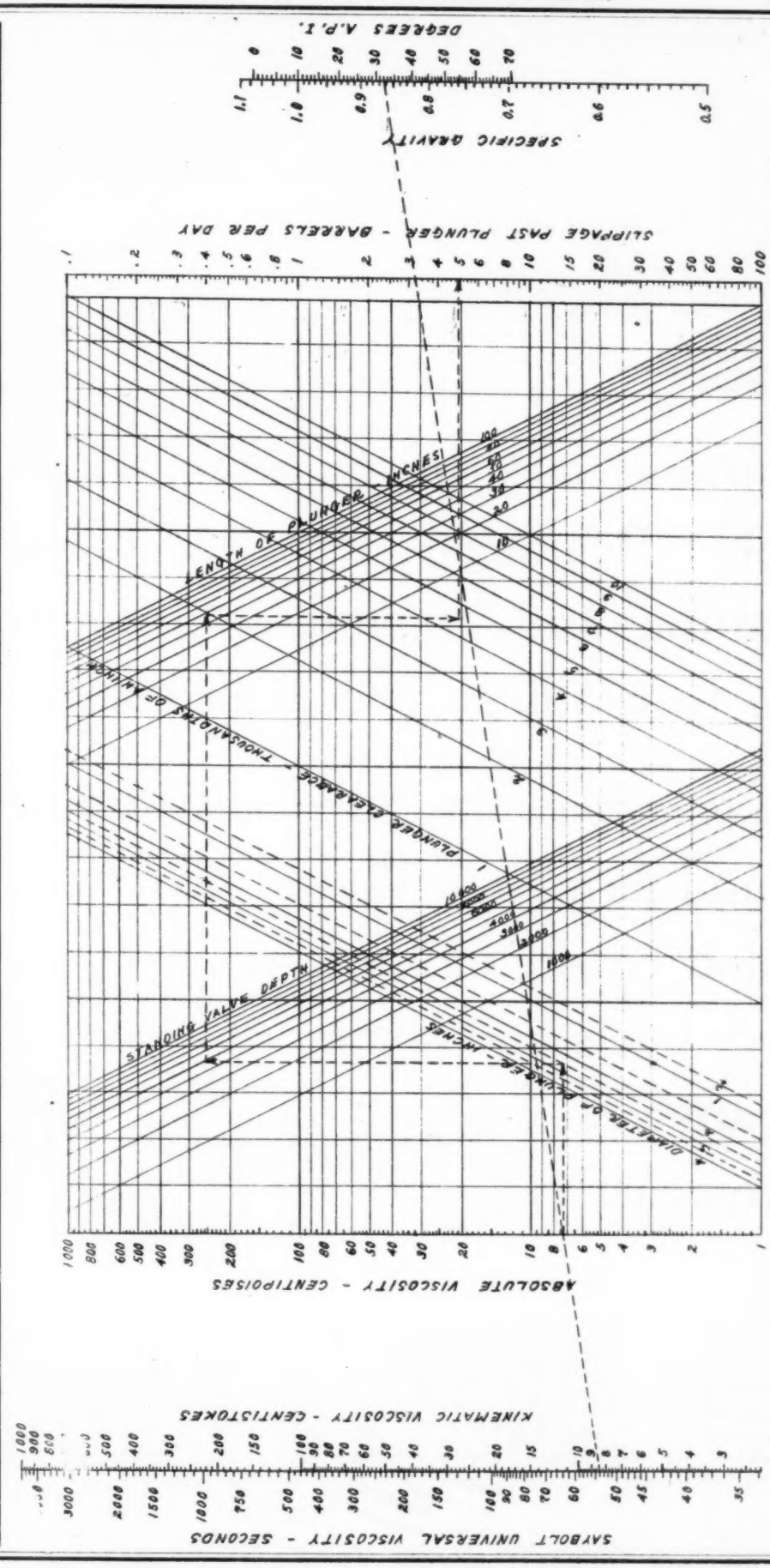
Be sure to investigate a G-Fin Unit for your next heating, cooling, condensing or heat transfer requirement.



THE GRISCOM-RUSSELL CO.
285 Madison Avenue
New York 17, N. Y.

GRISCOM-RUSSELL
TWIN G-FIN SECTION
The Universal Heat Exchanger

SLIPPAGE PAST PUMP PLUNGER


DEGREES A.P.I.
SPECIFIC GRAVITY
SLIPPAGE PAST PLUNGER - BARRELS PER DAY
LENGTH OF PLUNGER - INCHES
PLUNGER CLEARANCE - THOUSANDTHS OF AN INCH
STANDING VALVE DEPTH
DIAMETER OF PLUNGER - INCHES
ABSOLUTE VISCOSITY - CENTIPOISES
KINEMATIC VISCOSITY - CENTISTOKES
SAYBOLT UNIVERSAL VISCOSITY - SECONDS

Example

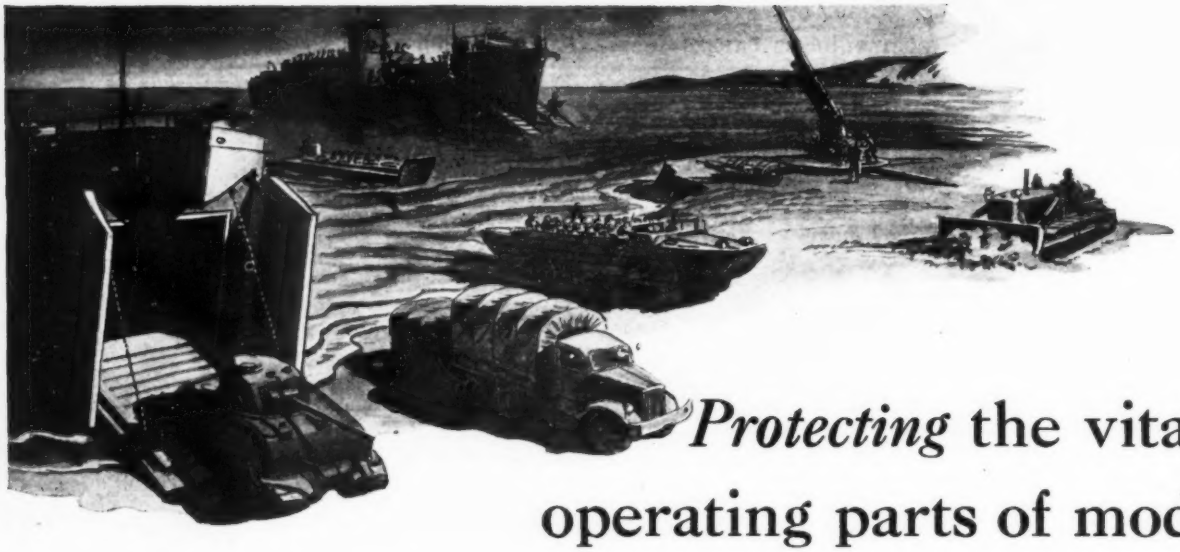
This chart is based on a consideration of Marsh's data, and a formula derived from the definition of viscosity which shows that slippage is inversely proportional to the length of the plunger and the viscosity of the oil and is directly proportional to the plunger diameter, the standing valve depth, and the third power of the plunger clearance.

Given: A 5000-ft. well equipped with a 2½-in. by 36-in. pump plunger with a clearance of 0.0045-in. on the diameter is pumping oil having an A.P.I. gravity of 32° and a Saybolt Universal viscosity of 54 seconds.

Required: What will be the slippage past the pump plunger in barrels per day?

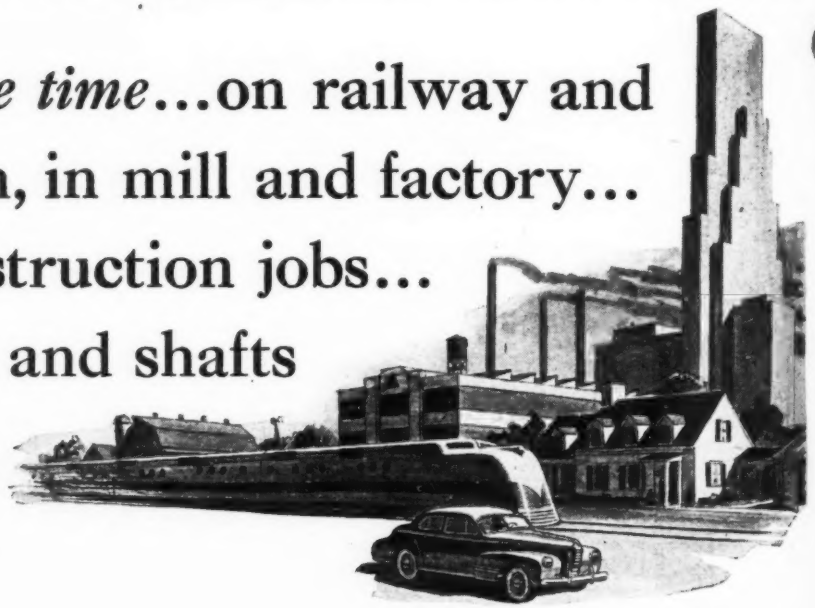
Solution: Lay a straight edge from 54 seconds Saybolt Universal viscosity on the vertical scale at the left hand side of the chart to 32° A.P.I. gravity on the right hand vertical scale, and read 7.3 centipoises absolute viscosity at the intersection on the intermediate vertical scale along the left hand edge of the chart block. Proceed horizontally from this point to a 2½-in. plunger diameter. Rise vertically to a 5000-ft. standing valve depth, continue horizontally to a 48-in. plunger length, drop vertically to a plunger clearance of 4½ thousandths of an inch, proceed horizontally and read slippage past pump plunger of 6 bbl. per day on vertical scale at right side of chart block. (To correct for gravity, multiply by specific gravity.)

—Chart by B. E. Curran, chief petroleum engineer, Kingwood Oil Company.

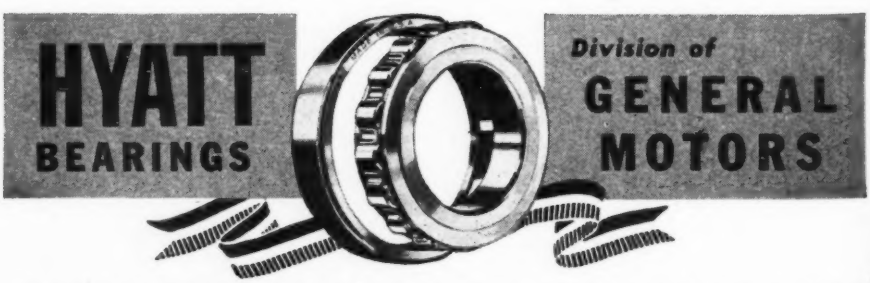


Protecting the vital operating parts of modern war equipment are the millions of care-free Hyatt Roller Bearings...into which we build great stamina and capacity, while holding them true to required precision tolerances...

And at the same time...on railway and highway and farm, in mill and factory... oil fields and construction jobs... wherever wheels and shafts turn...Hyatts are serving America!

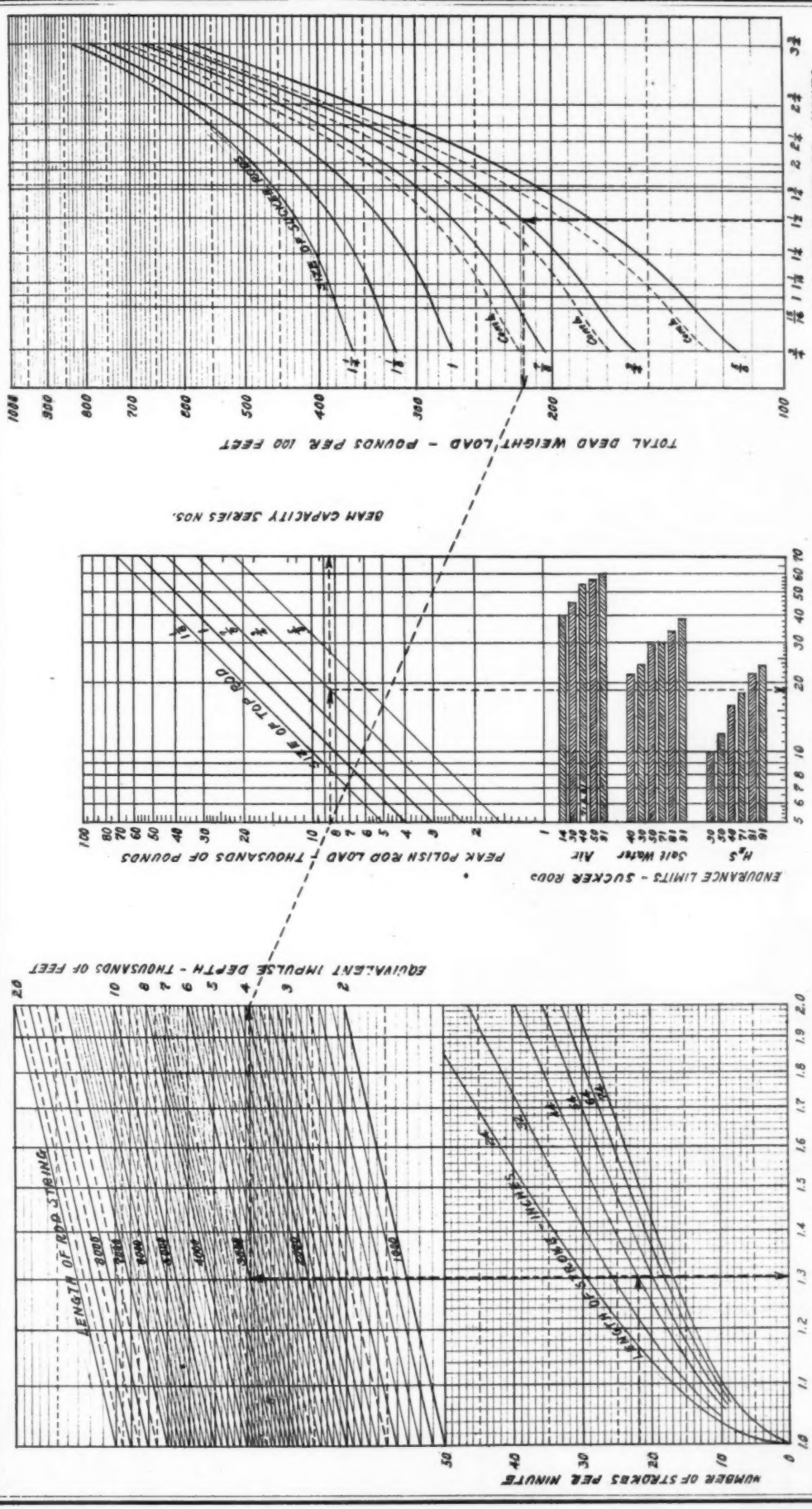


Hyatt roller bearings are built to last—and require a minimum of care. But don't forget to give them the proper attention all precious anti-friction bearings deserve today.



HYATT BEARINGS DIVISION · GENERAL MOTORS CORPORATION · HARRISON, NEW JERSEY

PEAK LOAD—BEAM CAPACITY—SUCKER ROD STRESS


TOTAL DEAD WEIGHT LOAD - POUNDS PER 100 FEET
PLUNGER DIAMETER - INCHES
SIZES OF SUCKER RODS
BEAM CAPACITY SERIES NOS.
PEAK POLISH ROD LOAD - THOUSANDS OF POUNDS
STRESS - 1000 LB. PER SQ. IN.
ENDURANCE LIMITS - SUCKER RODS
H2S
Salt Water
Air
EQUIVALENT IMPULSE DEPTH - THOUSANDS OF FEET
IMPULSE LOAD FACTOR
LENGTH OF ROD STRING
LENGTH OF STROKES - INCHES
NUMBER OF STROKES PER MINUTE

This chart is based on a modified version of Mill's formula.

Example

Given: A 3000-ft. well is equipped with a uniform string of ⅞-in. sucker rods and a 1½-in plunger, and is operated 22 strokes per minute, 44-in. stroke.

Required: What will be (a) the impulse load factor (b) the dead weight load per 100 ft. (assuming 10° A.P.I. gravity of fluid), (c) the peak polish rod load, (d) required beam capacity of pumping unit, (e) sucker rod stress in lb. per sq. in., and (f) grade of rods.

Solution: Enter left hand chart block at 22 strokes per minute on vertical scale at lower left, proceed horizontally to 44-in. length of stroke, and drop vertically to read impulse load factor of 1.3 on horizontal scale at lower left; proceed vertically upward from previous intersection to 3000-ft. standing valve depth, and continue horizontally to read (a) 3900-ft. equivalent impulse depth on right hand scale of left hand chart block. Enter right hand chart block at 1½-in. plunger diameter on horizontal scale at lower right, proceed vertically to ⅞-in. sucker rod size, and then horizontally to (b) dead weight of 219 lb. per 100 ft. of depth on left hand scale of right hand chart block. Connect the equivalent impulse depth with the dead weight load per 100 ft. and read (c) 8570 lb. peak polish rod load on intermediate scale on left side of middle chart block. From this intersection project horizontally to (d) required beam capacity of pumping unit on convenient scale at right side of middle chart block. From intersection of last horizontal line with size of top sucker rod on diagonal lines drop vertically to read (e) 19,000 pounds sucker rod stress on horizontal scale at bottom of middle chart block. Select (f) rod grade for operating medium by noting point where last vertical line cuts approximate endurance limit bar diagram.

—Chart by B. E. Curran, chief petroleum engineer, Kingwood Oil Company.

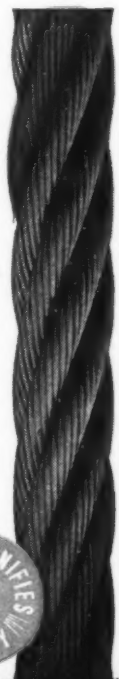
YOU WOULDN'T TAPE THE FINGERS OF A *pianist*

LAY·SET *Preformed* IS RELIEVED

Of course, this analogy is far-fetched but it is still true that the wires and strands of non-preformed wire rope are virtually locked in position—under constant stress—uncomfortable—cranky. Being so, non-preformed cannot work so well, nor long, as Hazard LAY-SET, which is preformed at the mill and entirely relieved of internal torsional stresses and strains. LAY-SET Preformed wire rope gives you greater dollar value, requires no seizing when cut; it resists kinking and whipping; it is easier to splice and safer to handle. And, invariably, it wears longer.

Ever since Pearl Harbor, and even before, Hazard LAY-SET Preformed has been saving time and money for the Government, the Armed Forces, and the taxpayer.

Specify Hazard LAY-SET Preformed for *all* its built-in advantages.



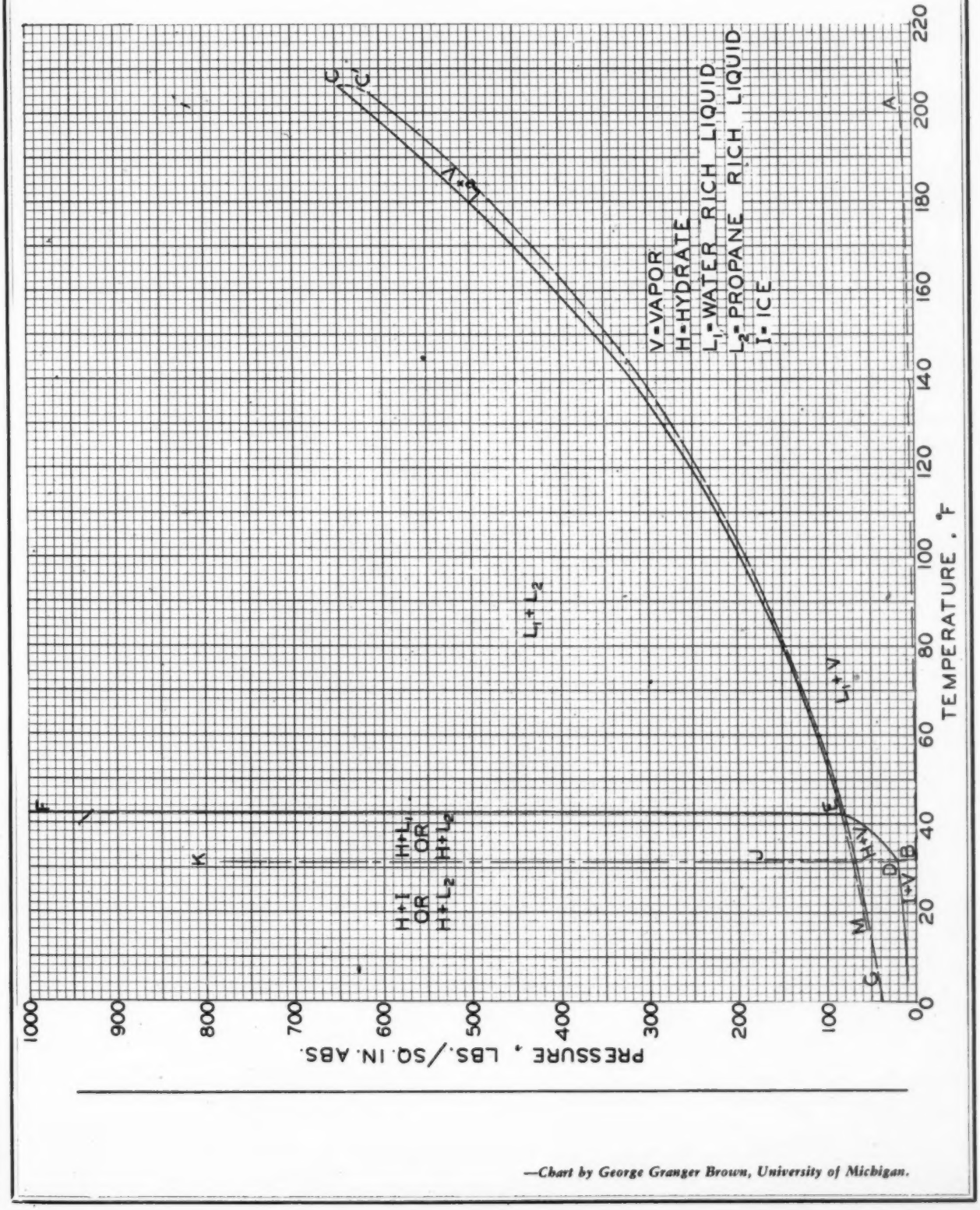
HAZARD WIRE ROPE DIVISION • Wilkes-Barre, Pa., Chicago, Pittsburgh, Fort Worth, Houston, Wichita, San Francisco, Denver, Los Angeles

Distributors in all important oil field centers

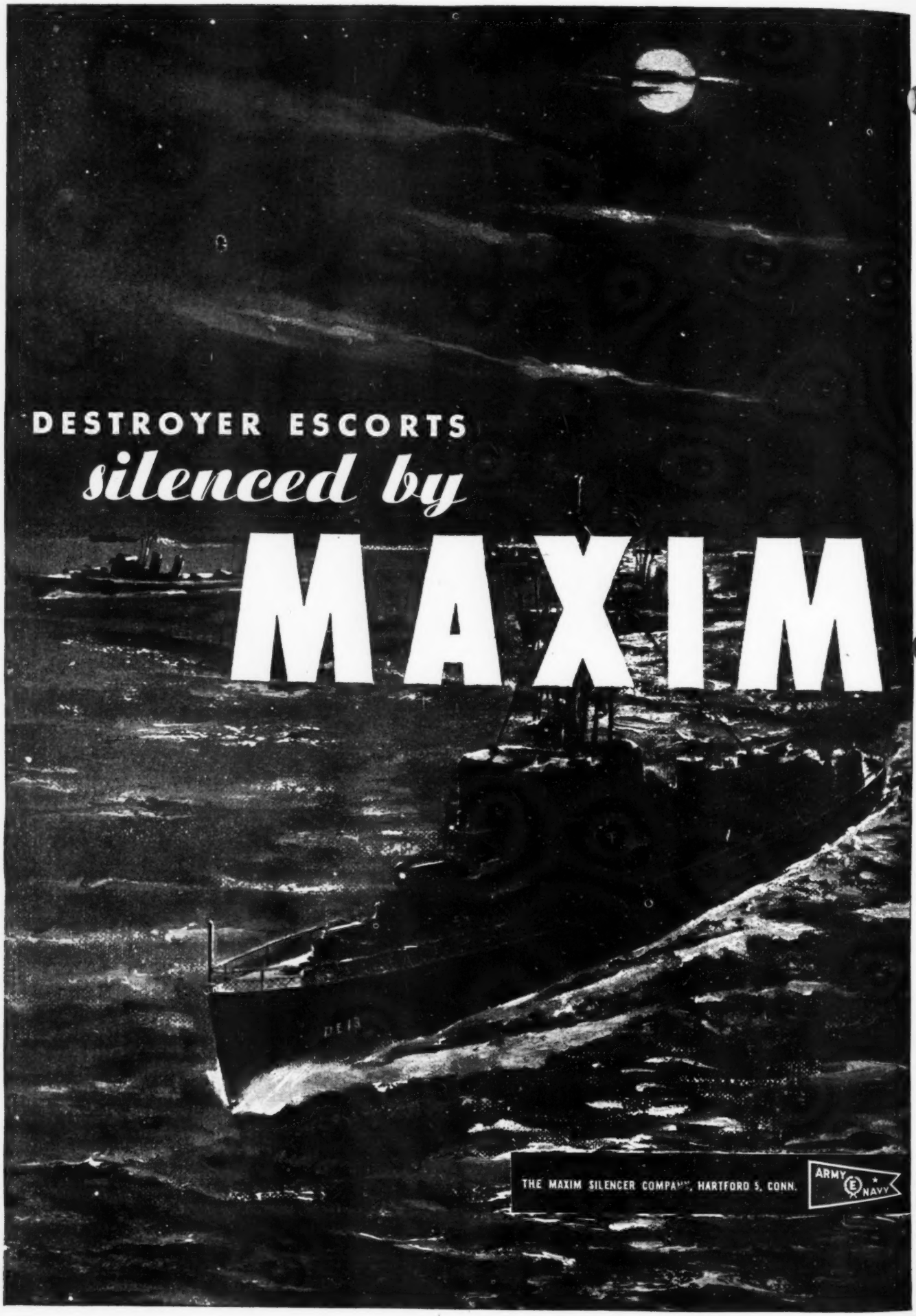
AMERICAN CHAIN & CABLE COMPANY, INC. • BRIDGEPORT, CONNECTICUT

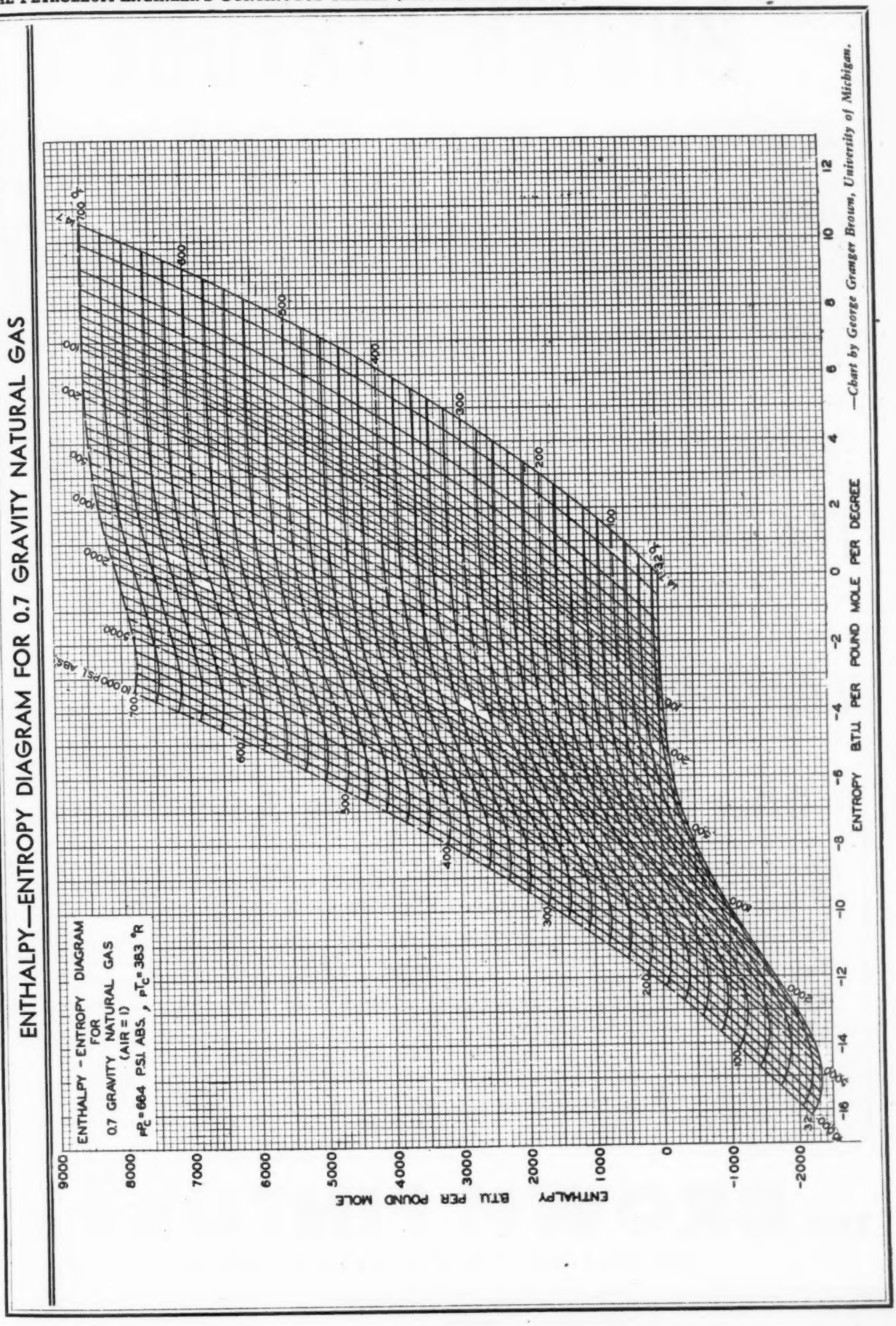
HAZARD LAY·SET *Preformed* ROTARY LINES

PHASE RELATIONS OF PROPANE-WATER SYSTEM



—Chart by George Granger Brown, University of Michigan.


DESTROYER ESCORTS
silenced by
MAXIM
THE MAXIM SILENCER COMPANY, HARTFORD 5, CONN.
ARMY E NAVY


ENTHALPY—ENTROPY DIAGRAM FOR 0.7 GRAVITY NATURAL GAS
ENTHALPY - ENTROPY DIAGRAM FOR 0.7 GRAVITY NATURAL GAS (AIR = 1)
P_C = 664 P.S.I. ABS., T_C = 383 °R
ENTHALPY BTU PER POUND MOLE
ENTROPY BTU PER POUND MOLE PER DEGREE
—Chart by George Granger Brown, University of Michigan.

BROWN FINTUBE

SECTIONAL HEAT EXCHANGERS

with this new
FLANGED HEAD
SEAL AND
FLANGED UNION

Patents Applied For

Offer These *exclusive* Outstanding Advantages

1. Flanged construction throughout,— eliminating screw fittings and screw unions,— and avoiding torsional strains on any member.
2. Gasketed seals eliminate ground joints, and all maintenance troubles common to ground joint construction.
3. Gaskets are renewable, fully retained, and joints may be *inspected easily* before sealing.
4. Seals may be made or broken with a small standard wrench,— from the front — permitting close side by side installation in minimum space.
5. This new flanged construction permits interior of fintube to be inspected and cleaned without disturbing shell side seal.
6. Sturdy rugged design, employing forged steel flanges with stud bolting. All joints have been tested to several times normal operating pressures.

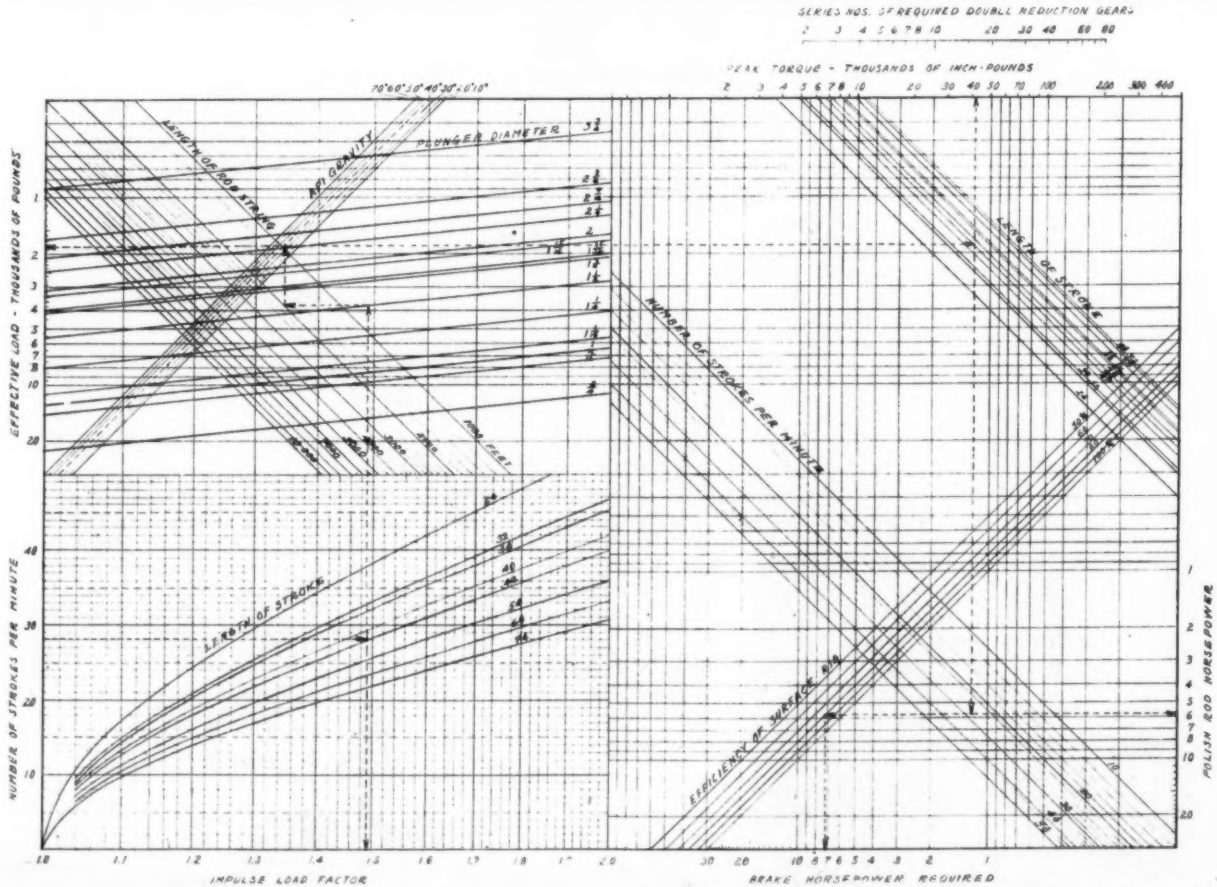
These exchangers are designed and built to give you a maximum of long, efficient, satisfactory service,— and to insure easy installation, easy inspection and easy maintenance by your workmen . . . Let us quote on your requirements.

THE BROWN FINTUBE CO.

125 FILBERT STREET • ELYRIA, OHIO

MANUFACTURERS OF INTEGRALLY BONDED FINTUBES AND FINTUBE HEAT EXCHANGERS

EFFECTIVE LOAD — PEAK TORQUE — HORSEPOWER


SERIES NOS. OF REQUIRED DOUBLE REDUCTION GEARS
PEAK TORQUE - THOUSANDS OF INCH-POUNDS
EFFECTIVE LOAD - THOUSANDS OF POUNDS
NUMBER OF STROKES PER MINUTE
LENGTH OF STROKE
PLUNGER DIAMETER
API GRAVITY
NUMBER OF STROKES PER MINUTE
EFFICIENCY OF SURFACE RIG
POLISH ROD HORSEPOWER
IMPULSE LOAD FACTOR
BRAKE HORSEPOWER REQUIRED

Example

This chart is based on Kemler's formula.

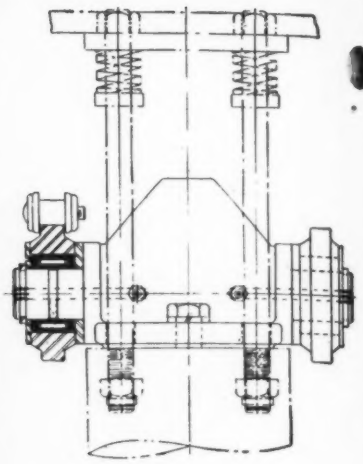
Given: An ideally counterbalanced 2000-ft. well, equipped with a 1½-in. plunger and operating 28 strokes per minute, 44-in. stroke, is pumping 40° A.P.I. gravity oil with a surface rig power transmission efficiency of 80 per cent.

Required: What will be (a) the impulse load factor, (b) the effective pumping load, (c) the peak torque, (d) the polish rod horsepower, and (e) the brake horsepower required?

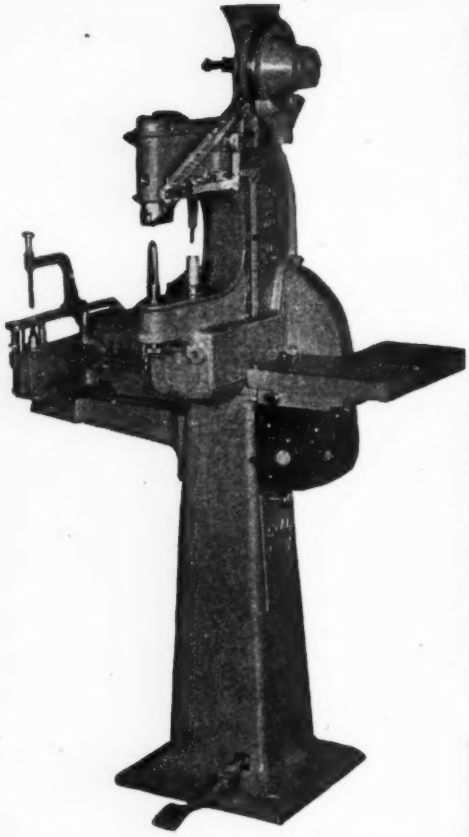
Solution: Enter chart at 28 strokes per minute on vertical scale at lower left, proceed horizontally to 44-in. length of stroke, and drop vertically to read (a) impulse load factor of 1.49 on horizontal scale at lower left. From previous intersection rise vertically to 1½-in. plunger, proceed horizontally to 2000-ft. standing valve depth, rise vertically to 40° A.P.I. gravity, and read (b) effective load of 1900 lb. on vertical scale at upper left. From previous intersection proceed horizontally to right to 44-in. length of stroke and rise vertically to read (c) peak torque of 42,000 in.-lb. on primary scale at upper right. (Capacities of required reduction gears can be conveniently set up on secondary scale). Drop vertically from peak torque to 28 strokes per minute and read (d) 5.9 polish rod horsepower on vertical scale at lower right. From previous intersection trace horizontally to the left to 80 per cent rig efficiency and drop vertically to read (e) required brake horsepower of 7.4 on horizontal scale at lower right. (Auxiliary scales can be arranged below brake horsepower scale for conversion to kilowatts where electric power is used.)

—Chart by B. E. Curran, chief petroleum engineer, Kingwood Oil Company.

IN THE NEWS
WITH TORRINGTON BEARINGS

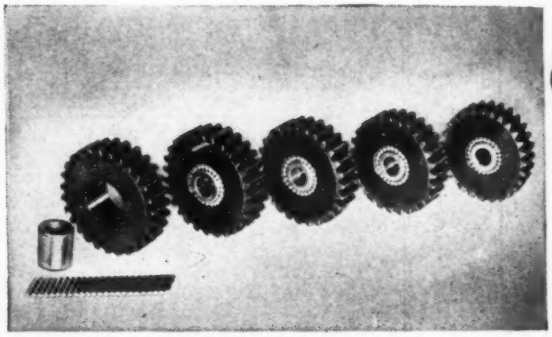


LIFT TRUCKS, manufactured by the Towmotor Corporation, are designed for the safe, rapid handling of multi-ton loads in around-the-clock service. To provide smooth operation in raising and lowering the load, Torrington NCS Needle Bearings are used on the hydraulic lifting cylinder crosshead. X-section clearly shows how compactness and high capacity of these bearings make them especially suitable for this interesting application.

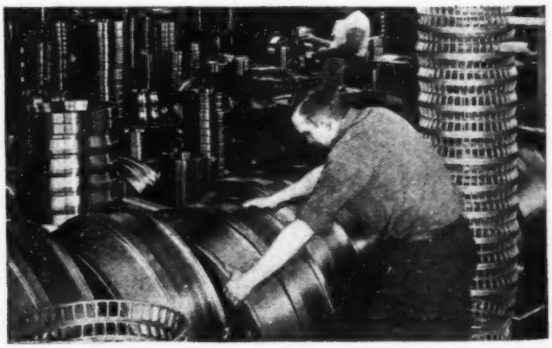


DELINING & RELINING of brakes is done rapidly and efficiently in a series of automatic operations performed by this brake relining machine manufactured by the Star Machine & Tool Company. Front and rear plungers, which perform the delining and riveting operations, operate at nearly 300 R.P.M. To reduce friction to a minimum, special Torrington Roller Bearings are used for the plunger rollers.

MORE THAN 150,000 Jahco airplane starters have been manufactured by the "associates" of Jack & Heintz, Inc. Noted for their dependability and instant response to the starter switch, Jahco starters are now used exclusively in all large combat and bombing aircraft. Due to the necessity for compact design and light weight, Torrington LN Needle Bearings were selected for use in the gears shown at the right.



"OUT OF THE ORDINARY" bearing applications are an important phase of Torrington's Engineering Service. The specifications may call for a bearing of unusual size, or special design. Frequently a bearing previously engineered for one application can be adapted to meet the requirements of another. Man in foreground in photo at right is handling the inner race of a large double-row tapered roller bearing, a type widely used in heavy-duty mill applications.



ARMY E NAVY

TORRINGTON BEARINGS

STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL

THE TORRINGTON COMPANY · BANTAM BEARINGS DIVISION

SOUTH BEND 21, INDIANA

CHART FOR CURRENT FLOW FROM POTENTIAL DROP

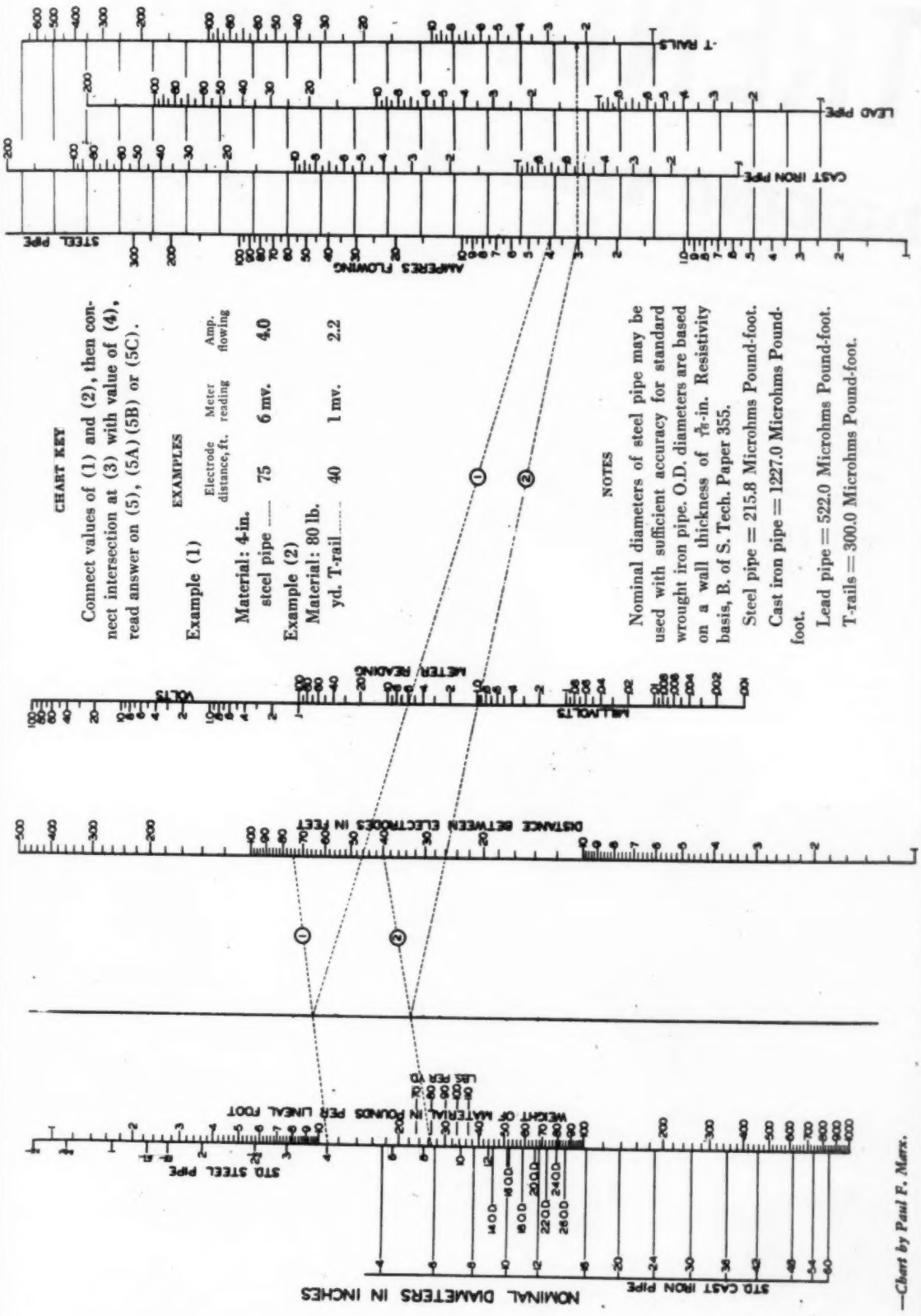


CHART KEY

Connect values of (1) and (2), then connect intersection at (3) with value of (4), read answer on (5), (5A) (5B) or (5C).

EXAMPLES

	Electrode distance, ft.	Meter reading	Amp. flowing
Example (1)			
Material: 4-in. steel pipe	75	6 mv.	4.0
Example (2)			
Material: 80 lb. yd. T-rail	40	1 mv.	2.2

NOTES

Nominal diameters of steel pipe may be used with sufficient accuracy for standard wrought iron pipe. O.D. diameters are based on a wall thickness of $\frac{1}{8}$-in. Resistivity basis, B. of S. Tech. Paper 355.

Steel pipe = 215.8 Microhms Pound-foot.
Cast iron pipe = 1227.0 Microhms Pound-foot.
Lead pipe = 522.0 Microhms Pound-foot.
T-rails = 300.0 Microhms Pound-foot.

—Chart by Paul F. Marx.

TRENCHLINER

DIGGING TRENCHES...

. . . with the Parsons improved 250 Trenchliner gives you the advantage of full crawler traction for solid footing . . . multiple travel and digging speeds for easy or tough digging . . . long and wide crawlers . . . low ground pressure, approximately 7 pounds per square inch . . . digging depth of 12'-6" . . . digging width 16" to 42" . . . shiftable, telescopic boom . . . power shift arc conveyor. All of these and many more have proven the operating economy, high production ability and low maintenance cost records. Now is the time to prepare for economical trenching . . . with a modern Parsons Trenchliner.

THE PARSONS COMPANY
Newton, Iowa

Parsons Model 250

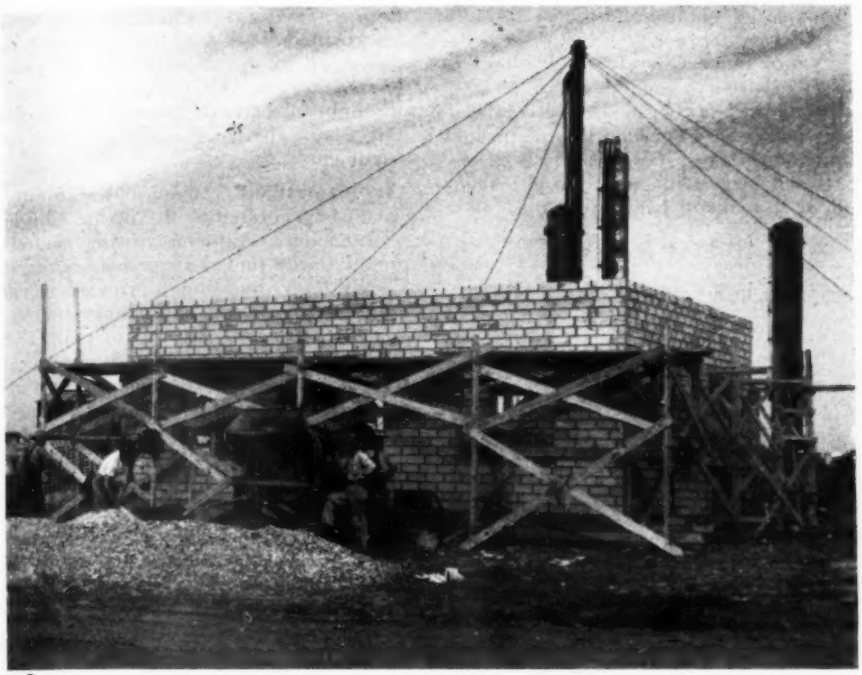
TRENCHING EQUIPMENT

PARSONS

CONSTRUCTING GASOLINE PLANT IN WAR TIMES

By DON ATTAWAY*

Salvaged material, equipment and local manpower can do the job all right



Constructing office and laboratory.

EXCLUSIVE The construction of a natural gasoline plant during the present day manpower and material shortages is a considerable problem even when highest priorities are available; but when the job is done with salvaged equipment, reclaimed material, and local manpower, it is a difficult, if not unusual performance, to say the least.

Such a condition faced the Arkansas Fuel Oil Company when it began the erection of its Carthage gasoline plant during December, 1943. The installation was necessary in order to procure the gas produced from some 6 wells in the new extension of the Carthage field, Texas.

The plant site is located approximately 9 miles northeast of Carthage on U. S. highway 79 and consists of 20 acres on the Panola Development Company Smith and Turner lease. When completed, the plant will process approximately 25,000,000 cu. ft. of gas per day for delivery into the Arkansas Louisiana Gas Company transmission and distribution system. In order to handle this gas, it was necessary for the gas company to extend its lines some 10 miles.

▼ **Problems faced.** Numerous and varied problems faced the construction supervisors. One in particular was the procuring of brass for use in making cooling tower foundation bolts. This was solved by the simple procedure of searching through the 11 company gasoline plant salvage and scrap piles for scored and discarded pump rods. Eventually, numerous bronze rods of various sizes were discovered and the most uniform of these were forwarded to the machine shop for turning down to size and threading.

The acquiring of absorbers, fractionator, tanks, preheaters, etc., was a lengthy and exhausting task of checking over all company plants for available equipment as well as inspecting idle and abandoned plants for towers, tanks, and material that might be reclaimed and redesigned to meet capacity and working pressure requirements. Obviously, many alterations in the original plans and arrangements followed as a result of this condition.

The main fractionator, a 4-ft. by 60-ft. tower, was an idle and aged piece of equipment when first secured and required considerable alteration. As originally installed, it was an absorber and contained a bundle of cooler tubes in its second section. This was removed and the two bottom sections interchanged. Specially designed bubble caps and trays were installed and alterations made for side-cut and charge connections. Being of riveted construction, considerable care was required in handling the vessel and in welding in the trays. At completion, the column met all hydrostatic tests satisfactorily.

The acquiring of steam generating equipment was another difficult problem, but several idle locomotive firebox oil-field type boilers were found in the oil production department of the company and, after minor repairs and fitting, they met state code requirements for operating at a pressure of 150 lb. per sq. in.

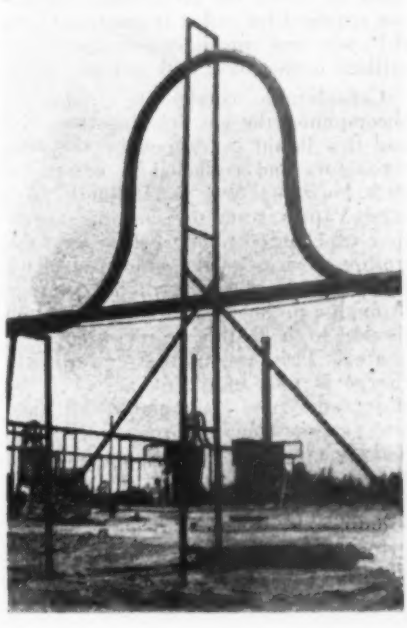
Absorbers, stabilizer, preheaters, pumps, condensers, and storage tanks were also obtained from other company plants not utilizing this equipment. Direct-fired heaters out of service at one plant were dismantled and after minor alterations and changes, were re-erected. Even the majority of the cottages erected for operating personnel were abandoned houses that were purchased and dismantled for movement to the plant site.

Many ingenious and unusual hookups were incorporated in the plant construction as a matter of necessity rather than intentional engineering.

▼ **Plant flow.** The plant is of the usual absorption type. Gas from the field gathering system enters the plant through two vertical separators and is measured through two 10-in. meter runs. The gas then passes into a header and enters the absorbers. One of these towers is a 4-ft. by 44-ft. column and the other is a 4-ft. by 30-ft. tower. Here the recoverable hydrocarbons are extracted and the dry gas passes from the top of the towers through the two 10-in. outlet meter runs. Back pressure control valves on these meter runs maintain a constant operating pressure of 400 lb. on the plant. The gas is given a final scrubbing through a 3-ft. by 16-ft. vessel before passing into the 12-in. main line.

The rich oil from the absorbers passes into a reabsorber where flash vapors are absorbed and thence through shell-and-

Expansion loop in steam line.



*Superintendent of Measurement, Arkansas Fuel Oil Company. Has been with this firm since 1930. Began his career with Dixie Gulf Gas Company in 1928 and spent a year with United Gas Company.

tube type steam preheaters. The oil is then given a final temperature treatment through a 20 tube direct-fired tube heater and charged into a 5-ft. by 45-ft. gasoline still. Overhead vapors are recovered and condensed in closed-type water coolers and collected in a horizontal 6-ft. by 20-ft. accumulator tank. The denuded or lean oil from the still completes its cycle by passing countercurrently through rich oil exchangers thence through coolers and into a 10-ft. by 16-ft. surge tank. Two 10-in. by 4½-in. by 10-in. duplex steam pumps take suction from the surge tank and discharge over the absorber and reabsorber to complete the cycle.

Construction scene. Oil field type boilers spotted on foundations.

Raw gasoline from the accumulator is charged into a 2½-ft. by 55-ft. stabilizer column and finished to the required vapor pressure grade. Overhead vapors from the stabilizer are condensed in closed-type water coolers and accumulated as reflux for the column. Liquid not required for reflux is produced as a B-P mix and uncondensed vapors are utilized in the plant fuel system.

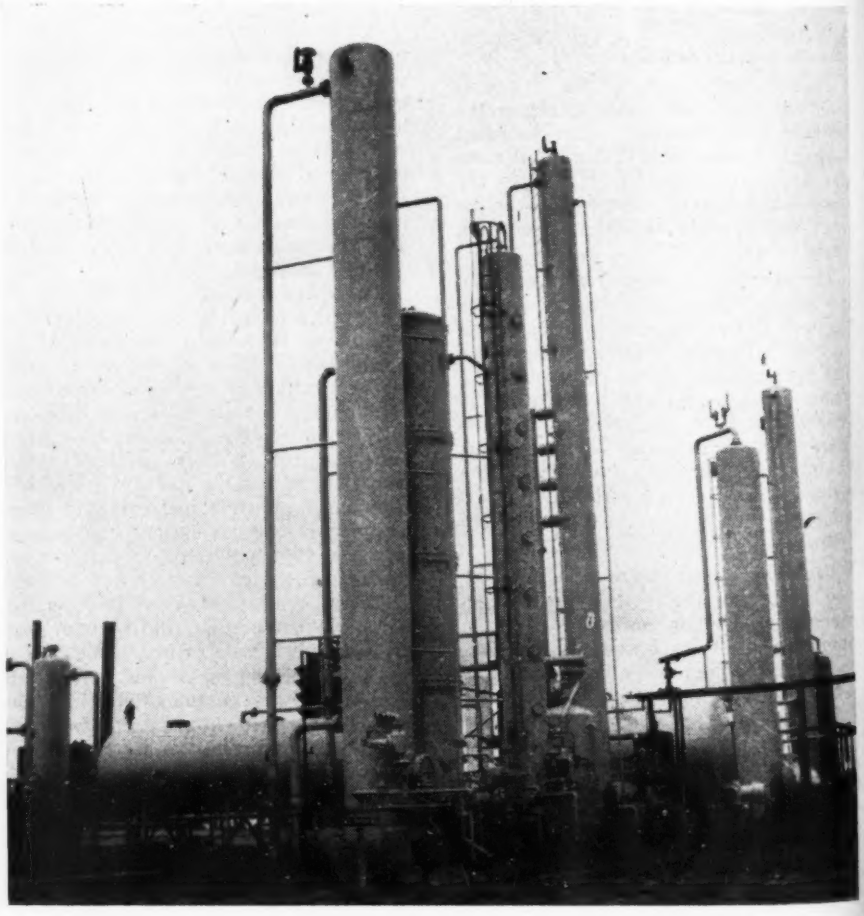
Considerable condensate production accompanies the gas entering the plant and this liquid is trapped by the inlet separators and collected in a 6-ft. by 20-ft. horizontal tank under 100-lb. pressure. Vapors from this flashing operation are charged to the reabsorber. Controlling devices on the condensate flash tank regulate the required charge through a preheater and flash tower and thence to a 60-tube direct-fired tube heater. This preheated condensate charge is introduced into the 4-ft. by 60-ft. redesigned fractionator. All flash tower vapors from the preheating operation are admitted to the column as a side charge. The first side cut on the fractionator is kerosine and this production is delivered into a 2-ft. by 20-ft. vertical stripper for control of flash point specification and thence through a cooler to storage. The overhead is passed through tube and shell water-cooled condensers and collected in the common accumulator for raw gasoline that serves the still. The bottoms are passed into a 16-in. by 15-ft. diesel fuel stripper for specification control and thence through a cooler to storage.

▼ **Vapor recovery system.** A complete vapor recovery system, utilizing a 2-stage 75-hp. gas engine driven compressor, has been installed. The plant fuel system utilizes waste vapors from all vessels and surge tanks and is supplemented by a makeup connection through a reducing valve on the gas outlet side of the plant. A constant pressure of 75 lb. is maintained on this system and any excess is diverted to the flare.

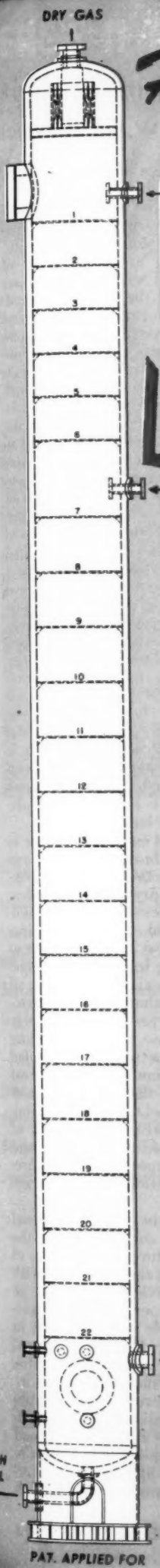
A 30-ft. by 50-ft. secondhand pipe fabricated frame building covered with corrugated iron has been erected to house all pumps required for the processing system. All controls have been brought to a central point in this building where one panel contains all the instruments.

▼ **Steam plant.** Steam power for the plant is generated by five 80-hp. oil field type boilers. Automatic firing controls regulate the fuel to these boilers. A 24-ft. by 90-ft. building fabricated in the same manner as the pump house is erected to house both the steam plant and the electric generating equipment. One 6-kw. steam-driven a-c. generator is installed for supplying the plant cottages. A 15-kw. steam-driven d-c. generator serves the plant requirements with a 25-kw. gas-engine-driven d-c. unit acting as a standby or emergency installation.

▼ **Water system.** Water for the plant operation was obtained by drilling a well on the plant site. This water well is 218 ft. deep and is flowed by means of a gas-engine-driven deepwell pump. At present, it has a capacity of more than 150 gal. per min. The plant water system is



Absorption, distillation, and fractionating units. Left to right—main absorber, second absorber, reabsorber, stabilizer, gasoline still, and condensate fractionator.



High Pressure Trim Oil System

LAGNIAPPE*

THE PRITCHARD HIGH PRESSURE TRIM OIL SYSTEM GIVES ADDED RECOVERY PER GALLON OF ABSORPTION OIL CIRCULATED

ABSORPTION SYSTEMS operating above 1200 lbs. (in the retrograde condensation range) require high initial boiling point absorption oils to prevent prohibitive absorption oil losses. This type oil is considerably harder to prepare and less efficient as an absorbent than lower boiling point oils. Therefore, it is advantageous to carry out the majority of absorption with a relatively low boiling point oil and to use a small amount of higher boiling point oil to prevent excessive light oil loss.

The higher the operating pressure the more pronounced will be the benefit of this Trim Oil System.

A plant to process 300,000,000 cu. ft./day of wet gas at 2250 lb. and 1250 lb. for 85 per cent Butane recovery is now under construction by J. F. Pritchard & Company, using this Trim Oil flow.

*Pronounced "Lan-yap." A word from the colorful vocabulary of the Louisiana French people, meaning "something extra . . . a gratuity from dealer to customer."

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supplied by two 45-hp. steam-turbine-driven centrifugal pumps, each having a capacity of 900 gal. per min. To supplement this water supply, an artificial lake of about two acres has been formed to serve as a spray pond. All steam pump exhausts are piped to a condenser situated at the boiler house. Water from the lake is picked up by a 45-hp. steam-turbine-driven centrifugal pump and discharged through a 4-in. water line to this condenser. A 10-ft. by 12-ft. make-up tank has been installed with connections so that its requirements can be supplied from the raw water of the well, the cooling tower, or the lake pump.

An 18-ft. by 48-ft. louver-type natural draft cooling tower constructed from California redwood has been installed. The tower is 36 ft. high and contains 7 cooling bays. The tower basin is approximately 20 ft. wide and 50 ft. long.

The piping arrangement of the water system incorporates an unusual feature in that opening and closing of three valves can reverse the water supply to coolers and condensers for back-washing operations even while all units are in full operation.

▼ **Storage.** Storage facilities for the finished gasoline consists of a 10-ft. by 30-ft. horizontal tank, a 10-ft. by 16-ft. horizontal tank, and one 2000-bbl. vertical tank. For kerosine, one 10-ft. by 10-ft. horizontal tank and one 1500-bbl. vertical tank have been installed. All diesel fuel production will be stored in a 10-ft. by 10-ft. and a 10-ft. by 30-ft. horizontal tank. Excess raw condensate production will go into an 8-ft. by 30-ft. horizontal storage tank. An 8-ft. by 12-ft. horizontal tank has been erected and fitted for butane production.

At the present time it is expected that all plant production will be moved by tank truck. Plans for pipe line and tank car movement have not been completed. A battery of three 6-in. by 4-in. by 6-in. pumps are installed in the pump room and so connected that they can be used for loading, charging, or rerunning. Another 6 by 4 by 6 pump at the same location serves as a charge pump for the raw condensate at such time as it may be required.

▼ **Buildings.** The plant laboratory and office is a 22-ft. by 30-ft. building constructed of hollow tile. Ample space is provided for the superintendent's office, a clerk's office, the laboratory, and a storage room. A direct telephone line from the plant to the main office in Shreveport, Louisiana, is in the final stages of completion.

Six frame cottages with all modern conveniences have been erected on the west side of the plant site for housing operating personnel. The plant proper is fenced with reclaimed pipe poles and wire. Night lighting is supplied by means of adjustable floodlights mounted on 30-ft. poles made from 6-in. junk pipe.

This plant makes the thirteenth for the company and the fifth in the East Texas area. Other plants are in Harrison, Marion, and Gregg county fields.

★ ★ ★

Importance of Internal Corrosion of Tubing*

By T. W. JOHNSON†

THE increasing importance of the problem of internal corrosion of tubing and wellhead equipment in gas-condensate wells is exemplified by the prominence this association has given in its program to the various aspects of the problem.

The information available at this time on the extent and occurrence of internal corrosion of tubing and wellhead connections is limited; however, there has been sufficient evidence of its existence in a number of fields to warrant the attention of both operating and research departments. Perhaps the most urgent aspect of the problem today is the need of an inexpensive method of determining where this type of corrosion is occurring and to what degree. The development of such equipment is anxiously being awaited by those responsible for the operation of gas-condensate wells. Wells and equipment cannot be operated with safety or assurance of continued service if the operating organization has no knowledge of the existence of corrosion until faced with such evidence as the failure of equipment. The research engineer will need some positive means of ascertaining in what wells corrosion is occurring and to what extent, in order to correlate the existence and intensity of corrosion with the actual operating conditions.

Some recent surveys of the gas-condensate wells have indicated wide differences in the rate of corrosion between wells and in the location of the corrosion within the tubing or wellhead equipment. In some wells in a field, there has been no evidence of corrosion while in others certain parts of the christmas tree or tubing have been severely attacked. With respect to the internal corrosion of tubing itself, most of the failures have occurred in the upper part of the tubing string; that is, the corrosion has been most concentrated in the first 100 ft. or so of tubing immediately below the christmas tree.

The replacement of equipment that has corroded to where failure has occurred, has proved to be very expensive in a number of instances. Also, in high pressure wells where the tubing has parted or large holes have developed near the top of the string it may be very difficult to kill the well preparatory to removing the tubing. In one well about 10,300 ft. deep, corrosion had resulted in a hole in the tubing about 300 ft. from the surface. In order to kill the well, it was finally necessary to snub under pressure about 6000 ft. of 1¼-in. diam. tubing through the 2½-in. diam. tubing and pump mud through the smaller size tubing. Operations such as these are expensive and must be performed with caution because there is no way at present of determining what piece or pieces of equipment are near the point of failure due to internal corrosion and the application of additional pressure during the process of killing the well would be dangerous. In the Gulf Coast area, a number of wells are equipped with the tubing set on a packer above the producing sand. The annular space between tubing and casing is filled with drilling mud. In one well so equipped gas pressure was noticed on the annular space between tubing and casing which indicated a leak had developed in or near the surface fittings. This well was located in the marsh lands and a drilling barge had to be moved in to rework the well. In order to remove the tubing it was necessary to cut it out in sections and the well was off production a total of 39 days. A thorough inspection of the tubing showed that the corrosion had been concentrated immediately below the christmas tree; however, internal corrosion had occurred near the upset part of a number of joints throughout the length of tubing string and parts of the christmas tree had corroded to such an extent that a new one was installed. The actual cost of this rework job was about $71,500 of which $7,800 represented the cost of the new 11,700 ft. of 3½-in. diam. tubing and $3,800 the cost of a new 10,000-lb. test christmas tree. The old tubing had been in the well for about 4 years. In these costs no allowance is made for the salvage value of the replaced materials.

Wells located and equipped similar to the one mentioned above are always comparatively expensive to rework; however, in the average high pressure gas-condensate fields it costs several thousand dollars to kill a well and remove the tubing, not including the cost of replacement of such items as tubing and christmas tree.

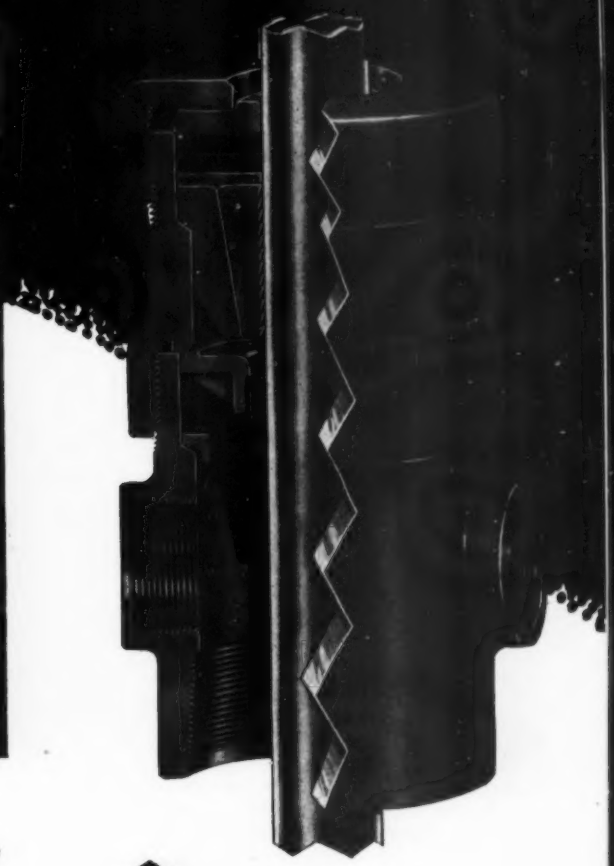
As mentioned previously, because of the uncertainty of where internal corrosion has occurred, precautions have to be taken that increase the cost of killing the well and replacing the corroded equipment. In addition to the actual cost of reworking a well there is the current loss in revenues due to the well being off production and also the necessity of having available additional wells and sources of supply to meet the gas requirements during the period when wells are off production.

It appears that the rate of internal corrosion might be correlated with the increase in temperature and pressure of the gas and if this is the case, then with deeper drilling, which would result in wells with high temperatures and pressures, it is reasonable to expect that in the future operating difficulties and expenses will increase unless some satisfactory solution to the problem of internal corrosion is developed. The problem of internal corrosion of gas condensate wells is certainly a part of the broad field of corrosion of pipe lines since the tubing and wellhead fittings are the first link in the transportation system. ★ ★ ★

*Presented before The National Association of Corrosion Engineers, Houston, Texas, April 10-12, 1944.

†Union Producing Company, Shreveport, Louisiana.

HERE'S A TIP ON TUBING HEAD ECONOMY



Type SR, Stripper type.

Type R, regular type when stripper is removed.

Many operators are effecting definite economies without any sacrifice of safety by removing expensive high pressure Christmas trees from wells where pressure has fallen off and replacing them with one of the strong, versatile Larkin Tubing Heads illustrated here. The Christmas trees thus removed can then be used in newer, higher pressure areas.

Larkin Tubing Heads, despite their low price, are suitable for gas lift, pumping or medium pressure flowing wells of any depth. Forged steel 4,500-pound construction provides ample safety factor. They are readily convertible from stripper type to regular type, and all parts for sizes from 4½" to 7" are interchangeable.

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Running Tour

WITH MEN IN THE INDUSTRY

▼ **F. W. Bruner,** production superintendent of Carter Oil Company's eastern division at Mattoon, Illinois, has been appointed acting manager of the company's northwest division. He fills the post vacated by **J. R. McWilliams,** Carter vice president and director, now on leave as director of the production division of PAW. **R. J. Sullivan,** assistant division superintendent and division engineer, has been named acting division superintendent, and **O. D. Harper** will serve as acting assistant division superintendent.

▼ **Peter M. Iverson,** 72, owner of the Iverson Tool Company, died July 25. His firm has branches in Oklahoma, Texas, Illinois, and Mexico.

▼ **M. J. Gavin** and **J. G. Detwiler** have been appointed assistant directors of the foreign refining division of PAW. Gavin's duties relate to the facilities side of the division, and Detwiler's primary responsibilities are connected with operation of foreign refineries.

▼ **A. H. (Burt) Lloyd** has been made head land man of the Sinclair Prairie Oil Company and Sinclair Wyoming Oil Company organization at Evansville, Indiana, succeeding **John E. Watson,** resigned, to join the British American Oil Producing Company staff.

▼ **Jack McClure,** production foreman with W. A. Delaney, Jr., since 1936, and **Sam Crump,** formerly with C. W. Roodhouse, have formed a partnership and established a business in recapping drilling bits with headquarters in Ada, Oklahoma.

▼ **H. A. Bierck** has been appointed purchasing agent of the Petrol Corporation, producers, refiners and marketers of motor fuels, lubricants, asphaltic products, and paints. He was formerly credit manager of the company, and fills the vacancy caused by the death of **R. J. Young.**

▼ **F. E. Rehm** has been elected vice-president of the Shell Oil Company, Inc. He has been with the corporation since 1916 serving in the production department, as production manager, as head of the industrial relations department, and since 1942, as manager of the industrial relations and personnel department.

▼ **Jay E. Miller** has been named advertising manager of the industrial products and sundries division of the B. F. Goodrich Company in addition to his duties as sales promotion manager of that division.

▼ **M. W. Field** has been appointed comptroller of the American Steel and Wire Company. He has formerly held positions with General Motors Corporation, Worthington Pump and Machinery Corporation, and Johns-Manville Sales Corporation.

▼ **W. A. Alexander** has been appointed acting production manager for the Texas Gulf Coast Area of the Shell Oil Company. He fills the vacancy caused by the death of **H. J. Kemler. J. Chalmers** succeeds Alexander as acting assistant production manager.

▼ **Roy Wm. Carver,** well-known oil executive and manager of the Richfield Corporation's land and lease department, resigned his position July 1 to enter private business.

▼ **Deming Bronson** has resigned as vice president and manager of Hill-Hubbell Division of General Paint Corporation.

▼ **Dr. Edward U. Condon,** associate director of the research laboratories for the Westinghouse Electric and Manufacturing Company, has been elected to membership in the National Academy of Sciences, membership in which is based upon outstanding contribution to the field of science.

▼ **W. B. Emery** was made vice president and manager of the production department of the Ohio Oil Company. He will have charge of exploration and development activities coordinating the work of the ten divisions of the company's production operations. Other officers appointed include **O. F. Moore,** to assistant manager of the pipe line department; **C. W. Krouse,** to manager of the Tampa, Florida, division; and **Fred J. Funk** and **John R. Donnell,** to assistants to the manager of production. **J. J. Frommer** became manager of the Shreveport, Louisiana, division May 1, and **R. C. Farley** was promoted to division superintendent of production at Shreveport. Earlier in the year **Fred E. Smith** was made general superintendent of production, and **R. M. Miller** was appointed to fill his former position as division superintendent of production in the Los Angeles, California, division.

▼ **J. S. Walton,** professor of chemical engineering at the University of Oklahoma, has returned to the University after a year's leave of absence during which he has acted as consultant for American contractors engaged in construction work in the Canadian Northwest and Alaska, and also served as a technical consultant for Rubber Reserve on problems connected with catalytic production of butadiene.

▼ **Errol J. Gay,** manager of the bus, truck, and fleet division of Ethyl Corporation, has been awarded the emblem for meritorious civilian service by the army for overseas achievement as a technical civilian adviser on petroleum problems.

▼ **J. H. (Harry) Allen,** formerly in the purchasing department of the Sun Oil Company, has been made assistant to **M. L. Brown,** production superintendent, covering Oklahoma and Kansas.

▼ **Walter B. Allen,** former production superintendent of the Bentex Oil Corporation and treasurer of the Midben Pipeline Corporation, has been promoted to the rank of major in the Marine Corps.

▼ **George Edward Dewey** has been appointed as manpower counselor to PAW, succeeding **F. H. Harbison. William C. Frysinger** and **John D. Kurtz** have been appointed assistant directors of the Foreign Supply and Distribution Division, and **A. P. Frame** was recently appointed director of the refining division of PAW to succeed **E. D. Cumming.**

▼ **H. E. Zoller** was elected president of the firm and its subsidiary, Darby Oil Company, succeeding **Carl Fisher. E. C. Claiborne** succeeds **Al Derby** as director and chairman.

▼ **George R. Prout,** formerly manager, industrial control division of General Electric Company, has been appointed manager of the air conditioning and refrigeration division of the appliance and merchandise department.

▼ **S. A. Berryann,** assistant export manager for the Brown Instrument Company, Philadelphia precision industrial instrument division of Minneapolis-Honeywell Regulator Company has been awarded the honor medal for the highest average attained in chemical engineering, junior year, at the Drexel Evening School, Drexel Institute.

▼ **Frank E. Bell** has opened offices in Laurel, Mississippi, under the name of Bell Land Title Company. He is carrying on a general abstracting business covering the states of Mississippi and Alabama.

▼ **Noel Robinson,** president of South Pennsylvania Oil Company, died July 17. He had been in the oil business since 1917 when he became associated with the Tide Water Oil Company in New. York. He became vice president and director of the South Penn Oil Company in 1940, and two years ago was named president.

▼ **R. B. Paxson** has been made chief geologist of Sunray Oil Company with offices in Tulsa. He was formerly with the Superior Oil Corporation recently merged with Sunray. **M. E. (Mark) Stump** will continue to be assistant geologist, and **H. S. McClintock,** vice president, will continue to direct the land department.

▼ **Jack Ballagh** of Patterson-Ballagh Corporation, Los Angeles, has returned to California after a 30-day business trip to the Mid-Continent fields.

▼ **Sir William Fraser's** son, Lt. Col. Ord William Fraser, will soon wed Miss Letitia Krementz, daughter of Mr. and Mrs. Walter Martin Krementz of Morristown, New Jersey. Sir William is chairman of the Anglo-Iranian Oil Company, Ltd., and subsidiaries.

▼ **Capt. Charles R. Wheeler** has been named field service representative of the Pennsylvania Grade Crude Oil Association, with headquarters at Chicago. He was discharged from the armed service in January after being wounded in action in Africa.

▼ **Jack Sutherlin,** manager of the Borger, Texas, office of Dowell, Inc., has been promoted to the Fort Worth office, effective this fall, succeeding **F. R. Holland,** resigned. **Nathan Webb,** station manager at Nocona, will succeed Sutherlin. **C. E. Mangold,** assistant general manager of Dowell, and **H. W. Ross,** assistant general sales manager, will have charge of the Fort Worth district until fall.

▼ **Albert E. Pierce** has been made vice president in charge of production for Mid-Continent Petroleum Corporation. He was promoted from general manager of production.

▼ **R. B. McHenry** has joined Gulf Oil Corporation in Tulsa as special assistant to S. G. Sanderson, general superintendent of production. He was formerly director of industrial and adult education in the Tulsa public school system.

▼ **Frederick Swank,** has been made manager of a new branch of National Cooperative Refinery Association at Shiloh, Ohio.

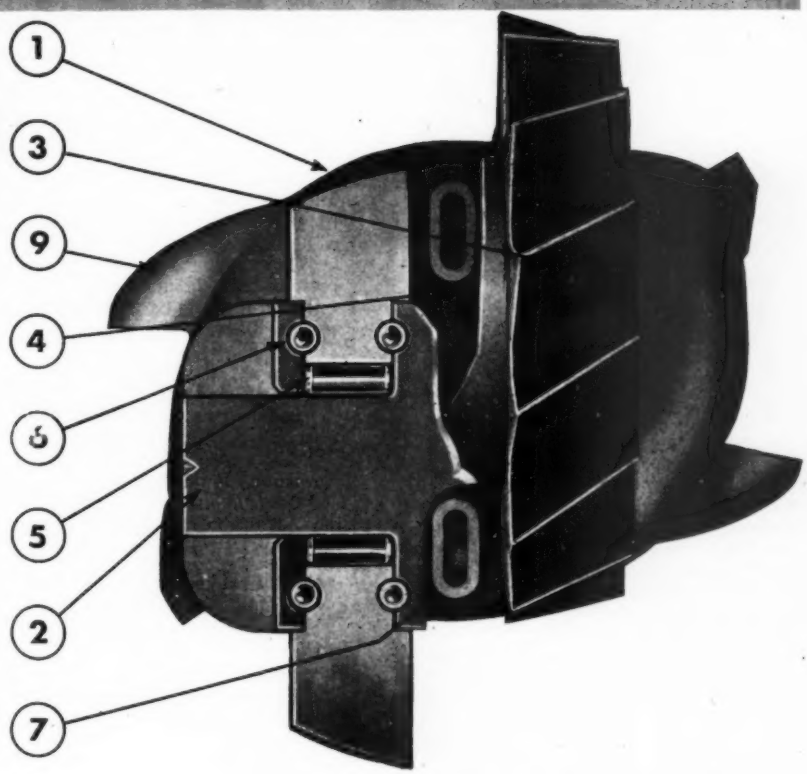
▼ **Louis Waterfall** has been appointed head geologist for Union Oil Company, succeeding **Earl B. Noble,** now in charge of all outside exploration.

▼ **William E. Glover** has been appointed assistant to the transportation manager of Ashland Oil and Refining Company. He has charge of dispatching river, rail, and truck shipments and coordinating crude oil supply with refinery requirements and transportation facilities.

▼ **Ronald M. Craigmyle** was named president and treasurer of Southwest Natural Gas Company. **R. H. Curry** is general manager.

GRANT

ROLLER CUTTER SHALE BIT



This bit has many advantages. Worn cutter assemblies can be easily removed and new assemblies welded in place, a feature especially important for operators in foreign fields. Cutters are extra large and properly hardfaced for long wear which results in fast and economical hole. Flow beans extend to the bottom of the bit, allowing circulation to strike bottom of hole without interference. Circulation is also directed over each cutter. Large side wings assist in holding hole to gauge. Roller bearings for radial load and ball bearings for thrust provide smooth operation and ample strength. Streamline design helps prevent excessive friction and balling up. Lost cutters or other working parts are practically unknown due to the ruggedness of trunnion and cutter assembly.

For complete information on the Shale Bit and other GRANT Tools, check and mail the coupon below.

Bottom view, half cross-section of GRANT Roller Cutter Shale Bit. (1) Shank. (3) Hardfaced Teeth. (9) Reaming Wings. (4) Washers. (6) Ball Bearings. (5) Roller Bearings. (2) Eccentric Trunnion. (7) Circulation Flow Beans. Cutters are available for soft, sticky Shale; medium Shale and hard Shale.

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STOODY TUBE BORIUM* KEEPS DITCHER TEETH SHARP ...ELIMINATES FREQUENT SHUT-DOWNS FOR TOOTH CHANGES...CUTS REPLACEMENT COSTS UP TO 75%

The two ditcher teeth pictured above were used on the same machine and operated under identical conditions.
The unprotected tooth at the top had to be sharpened every three days and was too short for further service after six sharpenings.
But the Borium-protected tooth at the bottom operated for 40 days and wore only ½". It was simply resharpened in the forge, retipped with Tube Borium, and put back on the ditcher for another 40 days' service.
Before the tooth was finally worn out, it had operated a total of 120 days!
Tube Borium makes such savings possible because the deposits represent the ultimate in wear resistance and the ability to cut hard earth formations.

*Stoody Tube Borium is supplied in rods of ⅛", 3/16", ¼" and ⅜" diameters and is available for either oxyacetylene or D.C. electric application. Prices and specifications are yours for the asking.

These tungsten carbide particles do not melt when tube is applied but are held in suspension in a mild steel matrix forming a deposit resembling coarse sandpaper.

Send for free booklet on TUBE BORIUM, showing sizes and styles of rods and recommended methods of application.

STOODY COMPANY
1142 West Slauson Ave., Whittier, Calif.

STOODY HARD-FACING ALLOYS
Stop wear... Eliminate Repair

LAUGH WITH BARNEY

A drunk ambled up to the ticket office and bought a ticket.

"You'd better sober up a little before you get on the train," warned the clerk.

The drunk drew himself up with dignity.

"Misshen, liser," he said. "I've only had tee martoonies and I'm not as much under the affluence of inkahol as some thinkle may peep, and the drunker I stand here the longer I get."

* * *

A man is that large irrational creature who is always looking for home atmosphere in a hotel and hotel service around the house.

* * *

Joe: My wife says that if I don't give up golf, she'll leave me.

Moe: Hard luck, I'd say.

Joe: Yes, I'll miss her.

* * *

After seeing a few samples we wonder why a Jap is so concerned about saving his face!

* * *

Women's slacks look all right at the cuff, but some of them look kind of funny around the bottom.

* * *

"They say that brunettes have sweeter dispositions than blondes."

"Well, my wife has been both and I can't see any difference."

* * *

After a pretty warm encounter with her immediate superior, Sally Stenog declared she knew why they called it a defense job when she went to work at that place.

* * *

Doctor: How's the patient this morning?

Nurse: I think he's regaining consciousness. He tried to blow the foam off his medicine.

* * *

Gob: What keeps your shoulder straps up?

Gal: Only your extreme timidity.

* * *

Visitor (at asylum): Do you have to keep the women inmates separated from the men?

Attendant: Sure, the people here ain't as crazy as you think.

* * *

Danny: Daddy is cofferdam a bad word?

Daddy: No, my dear, it is perfectly all right.

Danny: Well, my teacher has a cold and I hope she'll cofferdam head off.

* * *

Boss (sending the office boy on an errand): On the way you'll pass a baseball park.

Boy: Yes, sir.

Boss: Well, pass it!

* * *

Pat: Well, Doctor, how is Lawyer Smith today?

Doc: He's still lying at death's door.

Pat: Is he now? Well that's grit for you. At death's door and still lying.

* * *

"Boy, that was some blonde you were out with last night. Where did you get her?"

Sgt.: I don't know. I just opened my wallet and there she was.

* * *

He: We're coming to a tunnel. Are you afraid?

She: Not if you take that cigar out of your mouth.

* * *

Some of the girls have discovered that you get out of a sweater only what you put in it.

Two stuttering blacksmiths had finished heating a piece of steel and one placed it on the anvil.

"Hhhhhhhhit it," he stated to his helper.

"Wwwwwwwhere?" he was asked.

"Aw, Hhhhhhhell, we'll have to heat it again, now."

* * *

Wife: You're lazy, you're worthless, you're bad tempered, you're shiftless, you're a thorough liar.

Husband: Well, my dear, no man is perfect.

* * *

Upon inviting a friend to his wedding anniversary an Irishman explained: "We are on the 3rd floor, apartment D. Just touch the door button with your elbow."

"And why should I use my elbow?"

"Well, for heaven's sake, you aren't coming empty handed, are you?"

* * *

One of our modern young ladies, walking through the zoo, was surprised to find the monkey cages empty. Calling an attendant, she inquired the reason.

"Well, ma'am," replied the attendant, "this is the mating season when the monkeys remain in their houses for several days."

"Will they come out if I give them a peanut?" asked our young lady.

"Darned if I know," said the attendant. "Would you?"

* * *

A bathing beauty is a girl who has a wonderful profile all the way down.

* * *

"Mary, what's the reason for those cobwebs on the ceiling?"

"I don't know, Mum, unless there's spiders in the house."

* * *

"Say, Aunt Melissah, what am a paratrooper?"

"Honey, a paratrooper am a soljer what climbs down trees he never clumb up."

* * *

"Sarge," said Bill, the rookie, as the night patrol came in, "are the rest of the men back?"

"Yes," said the Sarge.

"All seven of them?"

"Yes, all here and all safe."

"Then," said Bill, the rookie, "I've shot a Jap!"

* * *

"Oh, Phil, it says 'Entire Balcony, 40 cents'."

"Well, what of it?"

"Let's get it so we can be all alone."

* * *

Two United States soldiers, sightseeing in London, were walking down Whitehall. They wanted to see the war office but did not know on which side of the street to look. They hailed a passing Tommy and asked:

"Which side is the war office on?"

The Tommy thought a startled moment and replied, "Gorblimey! Ours, I think!"

* * *

"Marry my daughter? Ha! Young man you couldn't even keep her in underwear."

"There are times, sir, when you don't do so well at it yourself."

* * *

A sweet young thing from the window, "Say, iceman, do you have the time?"

"Sure, but who's going to hold the horses?"

* * *

He: Hello, Beautiful. I understand you are no longer a struggling steno.

Gal: No, when I quit struggling I found I didn't need to be a steno.

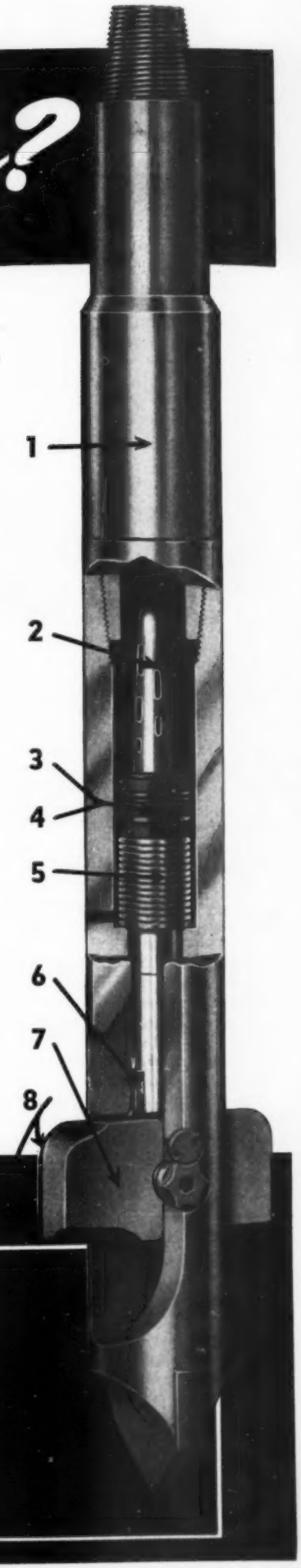
Are You a Quiz Whiz?

Every man in the drilling and producing branches of the oil industry should know the answers to the following questions as to the design, construction and operation of the Baker Rotary Wall Scraper. They are factors which directly affect the proper drilling and completion of any oil well to make it a profitable, long term investment.

If you know the answers to 6 questions you rate a QUIZ WHIZ rating of fair; 7 answers, medium; 8 answers, good; 9 answers, expert; 10 answers, super; 11 correct answers, super-duper. No time limit! Don't peek at answers below until you have studied *all* the questions and are ready to know your QUIZ WHIZ rating.

1. Name this simple part.
2. What is the purpose of this cone-shaped screen?
3. This Plunger Head is provided with oil-resistant seals. Why?
4. Why are two of the seals facing up, and one down?
5. Why is a Plunger Spring used?
6. What is the purpose of this Circulation Bean (or bushing)?
7. Why are the blades made of hard, tough alloy steel forgings, with cutting edges set with tungsten carbide inserts?
8. Why is the vertical scraping surface of the blades so great?
9. The reaming capacity of Baker Wall Scrapers is really amazing. What is the minimum and maximum reaming gauge of the full complement of sizes?
10. Give three important uses for the Baker Rotary Wall Scraper.
11. What company originated this tool and provided the name?

Confidentially, how did you make out? There are many other important features about the Baker Rotary Hydraulic Expansion Wall Scraper which you should know if you have anything to do with the drilling and completion of oil wells. May we suggest that you turn to Page 361 of the 1944 Composite Catalog to see how this successful tool will fit into your operations. If you prefer the separate Baker 1944 Catalog, the nearest office will be glad to supply you with one.

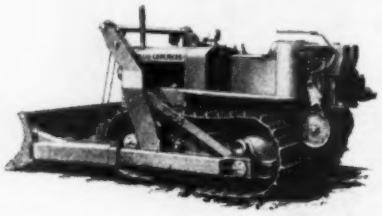


BAKER OIL TOOLS, INC.

MACHINERY and EQUIPMENT

Buckeye dozer

A new cable-controlled side-lift bulldozer and trailbuilder featuring single king pin mounting of the moldboard and double trunnion tilting has been announced by The Buckeye Traction Ditcher Company, Findlay, Ohio. The moldboard of the trailbuilder can easily be angled to the right or left on the single king pin simply by removing two landside pins, swinging the blade to the desired side, and replacing the landside pins that hold it rigidly in place. The double trunnion mounting makes it possible to tilt either end of the blade 12 in. by attaching one push arm to the top trunnion on one side while the other arm is mounted on the lower trunnion on the opposite side.



The horn and push frame, which have been completely redesigned, are fabricated from heavy steel welded box-beams to provide maximum strength. The rugged construction of the moldboard is another of the exceptional features of the new dozer. Welded V-shaped vertical braces and heavy steel plate horizontal cross pieces reinforce the blade so that it can withstand the toughest bulldozing operation. Moldboard is fitted with reversible cutting edge and replaceable corner bits.

The new dozer is track mounted with the weight evenly distributed over the crawler shoes to provide maximum traction. Single or double drum Buckeye power control units provide the necessary power.

Electronic recorders

Release of an electronic circular chart electric controller for manufacture of either war or civilian goods is announced by the Brown Instrument Company, Philadelphia precision industrial instrument division of Minneapolis-Honeywell Regulator Company. This is one of the first of its several electronic instruments to be released in quantities and with no rationing system planned.

The electronic recorder of the type released is being used in, and is of special interest to, the metallurgical and chemical industries. The release stipulations specify 8 weeks for delivery of two models. Each model will have several new features, including a control point index that is in red and of the same general shape as the black temperature pointer.

In making known the release of the electric contact circular chart electronic potentiometer, the company also stated that other electric control models will be announced as soon as they are available.

Outdoor a-c. welders

Two new outdoor a-c. welders, a 500-amp. type and a 300-amp. type, have been announced by the Electric Welding Division of the General Electric Company. The 500-amp. welder has a current range from 100 to 625 amp., and the range of the 300-amp. welder is from 60 to 375 amp.

These welders are equipped with an "idlematic" control that functions to reduce the output voltage automatically to less than 30 v. whenever the arc is not in operation, yet provides full power for welding directly the arc is struck. In addition, this control is provided with a switch, conveniently operated by a handle projecting through the top of the case, for shutting off the welder when not in use.

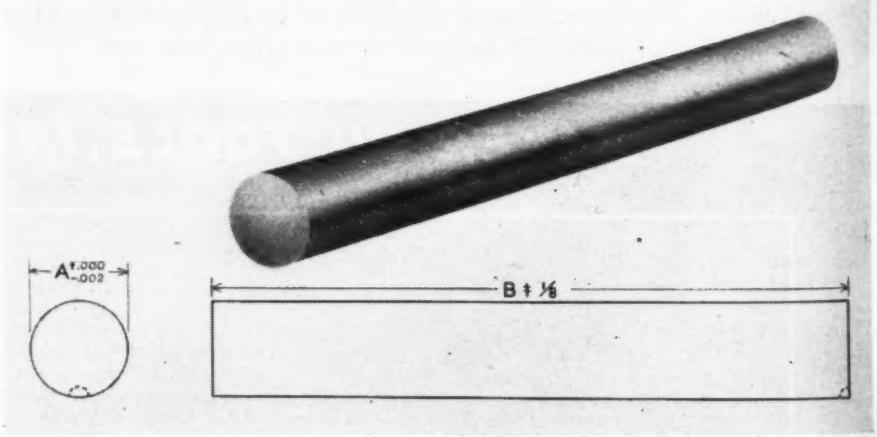
Protection against the entrance of rain, snow, and sleet is provided by the dripproof construction of all openings

in the top of the sturdy enclosures of the welders, and by a sealed window over the current indicator. The ventilating openings serve both to shed water and to keep air velocity low. A special finish on all internal parts provides protection against corrosion from moist air.

These welders also incorporate all the desirable features of General Electric indoor a-c. welders of this type, including built-in power-factor improvement, fingertip adjustment, stepless current control, and fan-forced ventilation.

Round tool bits

Round tool bits, made either from Stellite 98M2 or Stellite Star J-Metal alloy, are supplied by Haynes Stellite Company, a unit of Union Carbide and Carbon Corporation, Kokomo, Indiana.

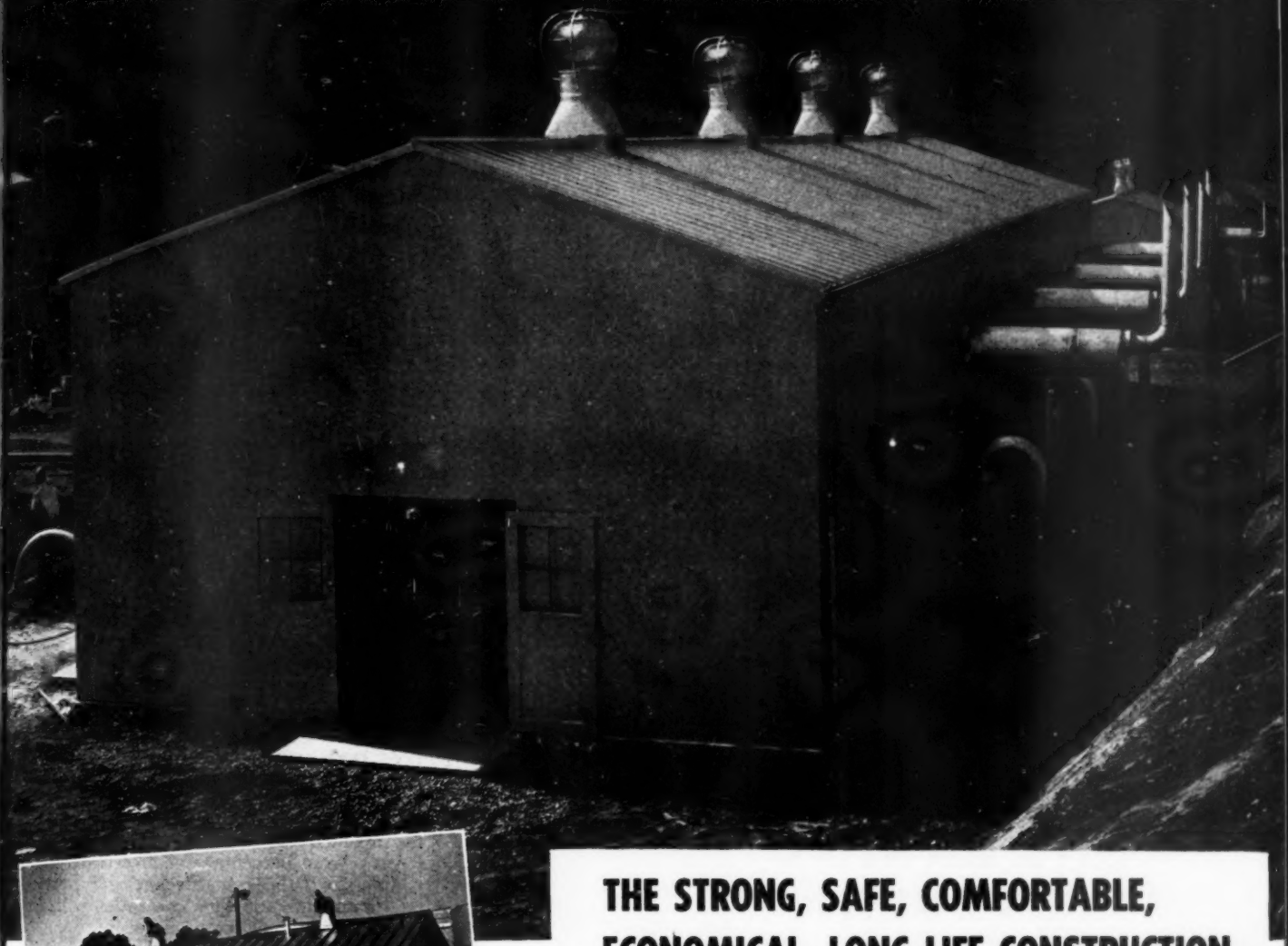


These round tool bits are supplied centerless-ground to tolerances of plus 0.000 and minus 0.002 in. on the diameter, and plus or minus 1/16 in. on the length.

Stellite round tool bits are used on turning or boring operations, or can be ground into drills or reamers. They possess the same red hardness, edge strength, toughness, and abrasion resistance as Stellite square and rectangular tool bits. Tool bits of 98M2 are made for faster machining of steel; Star J-Metal has long been used for machining cast iron, malleable iron, bronze, brass, aluminum, and some steels.

Further information on Stellite round tool bits may be obtained from Haynes Stellite Company, Kokomo, Indiana.

STEELOX BUILDINGS



STEELOX comes to you in sections, with interlocking joints making weather and dust-tight connections, and with all accessories for complete building. Easily and quickly erected without skilled labor.

See pages 2396-97, your 1944 Composite Catalog, or ask your Parkersburg representative for details.

THE STRONG, SAFE, COMFORTABLE, ECONOMICAL, LONG LIFE CONSTRUCTION FOR THE OIL INDUSTRY'S

- PUMP STATIONS
- REFINERY BUILDINGS
- BULK STATIONS
- DOCK AND WHARF BUILDINGS
- GATE HOUSES
- TOOL HOUSES
- BUNK HOUSES
- METER HOUSES
- BOOSTER STATIONS
- GASOLINE STATIONS
- MACHINE SHOPS
- MESS HALLS
- MISCELLANEOUS HOUSING

THE PARKERSBURG RIG & REEL CO.

PARKERSBURG & OCS PRODUCTS
GENERAL OFFICES, PARKERSBURG, W. VA.
Plants at Parkersburg, W.Va., Coffeyville, Kan.
District Offices
Dallas - Houston - Los Angeles - Tulsa
New York

OCS

PARKERSBURG

Fuel oil clarifier

Briggs Clarifier Company, Washington 7, D. C., announces an improved standard line of round tank fuel oil filters for diesel engines. New models have been added to broaden the application of Briggs fuel oil clarifiers so that flow capacities range up to 500 gal. per hr.

Maximum working pressures and hydrostatic test pressures have been established to meet specific demands of the application. For small high speed diesel engines where pressures sometimes run well above 50 lb. per sq. in., the clarifier is designed for a maximum working pressure of 100 lb. per sq. in., and is hydrostatically tested at 150 lb. per sq. in. For large, heavy duty diesels where pressure is usually between 15 and 25 lb., the clarifier is designed for a maximum working pressure of 40 lb. per sq. in. and hydrostatically tested at 60 lb. per sq. in. Pressure drop across the refills ranges from 0 to 5 lb. per sq. in. on all models.

Provision is made for registering pressure differential across the refill cartridges by installing one gauge in the upper compartment of the tank and another in the lower compartment.

Spot welding timer

Suitable for welding small objects of high conductivity such as aluminum or copper, a new precise welding timer with heat control for timing intervals of one-half cycle or less is announced by Westinghouse Electric and Manufacturing Company.

The timer is supplied as a separate control for use with existing small bench welders and also in combination with a small welding transformer. Only one control tube is used, this thyratron serving the dual purpose of rectifying alternating current to charge a firing capacitor and also firing the small ignitron power tube. Heat control is accomplished by a phase shift method, the adjustment dial for which is mounted on the cabinet door.

Type SP-18 spot timer, showing accessible swing-out panel.

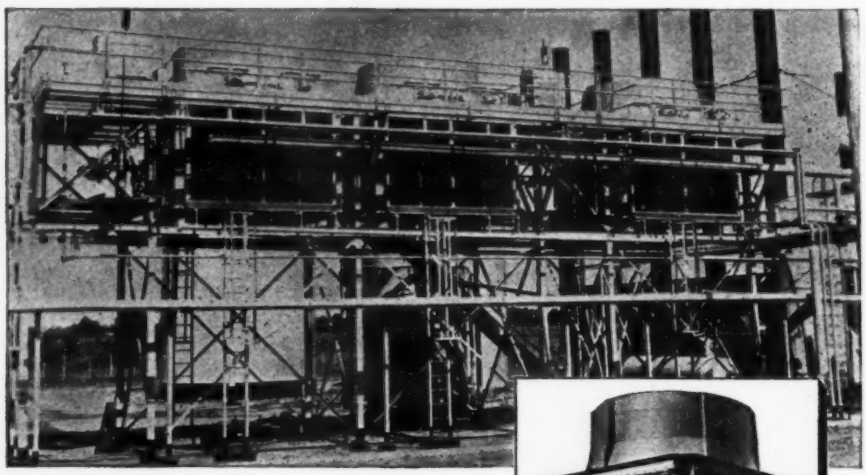
Further information on this timer, rated at 230/460 v., 50/60 cycles, may be obtained from Department 7-N-20, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

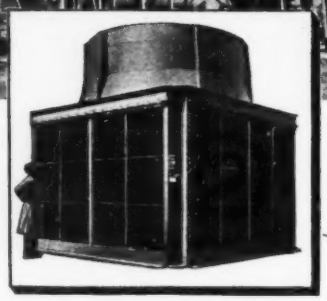
Rotameter controller

If a ratio flow control problem exists in which it is desirable to keep one flow at a fixed percentage of a second variable flow, the new Fischer and Porter Rotamatic ratio flow controller will do the job automatically, according to the manufacturer. Furthermore, the ratio may be varied at will by a turn of the flow ratio button.

The operation is as follows: Two rotameters with electric transmissions for remote readings are placed in the respective flow streams. The remote flow-responsive balance beams from these two rotameters are placed back-to-back and connected by a cross beam. From this cross beam is suspended an arm whose position may be changed at will by sliding it on the beam. This suspension arm is connected to a Rotamatic air-operated control mechanism, which in turn transmits air pressure to an air-operated control mechanism, which in turn transmits air pressure to an air-operated valve in the flow line of the stream, which is to be maintained at a fixed percentage of the main flow. Thus, the position of the arm suspended on the cross beam determines the flow ratio of one stream to the other. The ratio may be readily maintained at any point from 1/5 to 1 up to as high as 5 to 1 by moving the ratio index button. Liquid flows from 1 gal. per min. up to 6000 gal. per min. may be proportioned, and gas flows in equivalent volumes.

Full details will be sent on request to Fischer and Porter Company, 989 County Road, Hatboro, Pa.





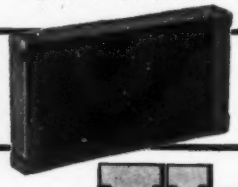
CONDENSING 40,000 POUNDS of Steam Per Hour

Capacity at 10 pounds gauge pressure

★ This unique installation of 3 Young—Happy Quad Condensing Towers was recently completed for a Southern Illinois refinery engaged in the production of Iso-Butane and Butane for the synthetic rubber program. Here's another outstanding example of Young engineers' ability to adapt "standard" Young products to specialized assignments. Young Quads and Young Evaporative Coolers and Condensers are receiving recognition in the oil, gas and synthetic rubber fields for their highly efficient operating features. Write for engineering data.

YOUNG RADIATOR CO., Dept. 284-H, Racine, Wis., U. S. A.

Distributors: The Happy Co., Tulsa, Oklahoma • A. R. Flournoy, Bell (Los Angeles), California Wrightson-Campion, New York, N. Y. • W. P. Nevins Co., Chicago, Ill. • Calmes Engineering Co., New Orleans, La. • Export: Ameresco, Inc., New York, N. Y.



YOUNG COILS embody patented construction features; are widely used in heating, air conditioning, evaporating and condensing systems. All are thoroughly tested and accurately rated. Representatives in principal cities.

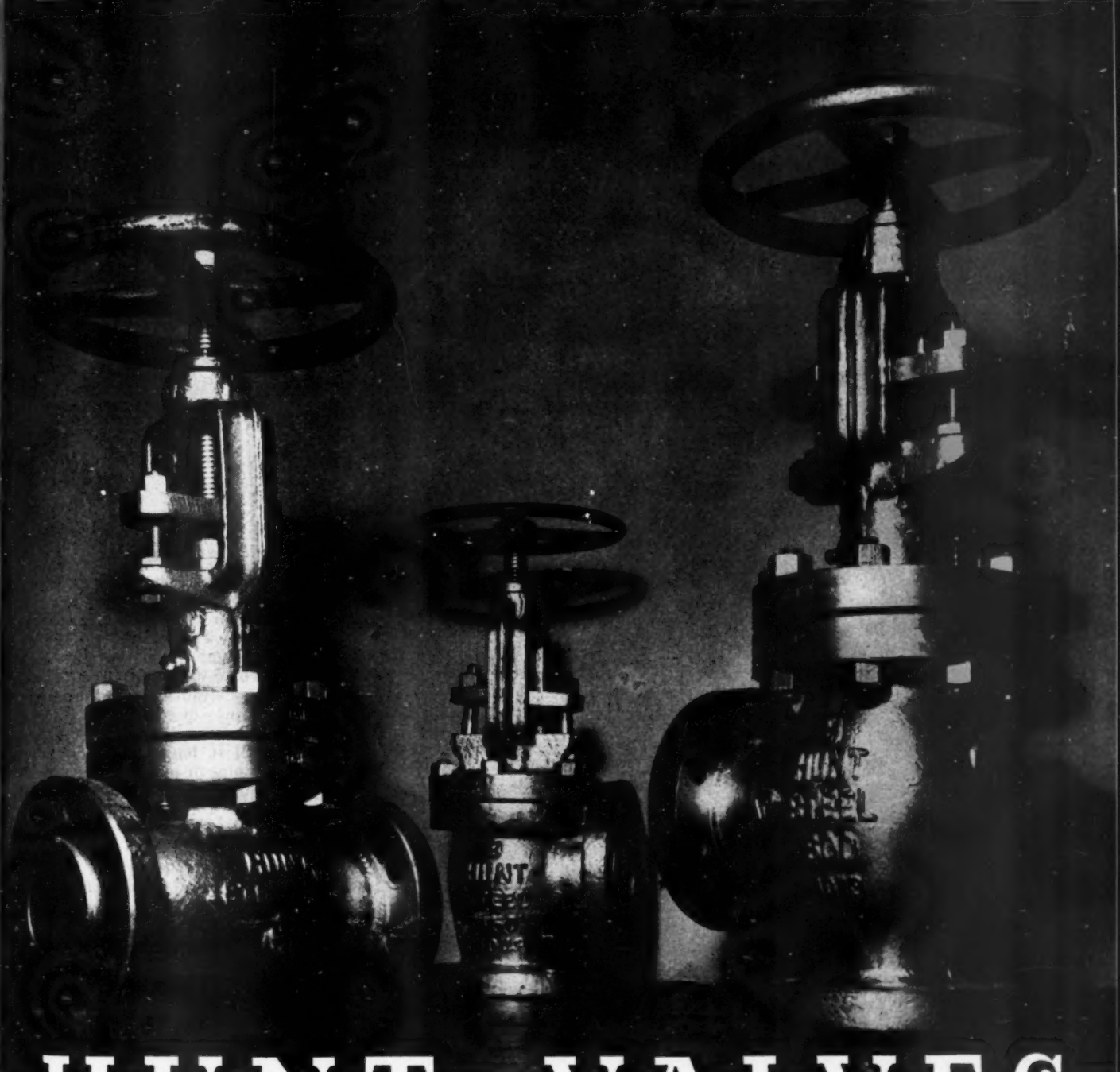
YOUNG

BUY BONDS PRODUCE MORE SALVAGE SCRAP WIN THE WAR

HEAT TRANSFER PRODUCTS

Oil Coolers • Gas, Gasoline, Diesel Engine Cooling Radiators • Intercoolers • Heat Exchangers • Engine Jacket Water Coolers • Unit Heaters • Convectors • Condensers • Evaporators • Air Conditioning Units • Heating Coils • Cooling Coils • and a Complete Line of Aircraft Heat Transfer Equipment.

DEPENDABLE



HUNT VALVES

Full details on the complete line of Hunt Valves gladly furnished upon request.

FIELD SHOPS
Houston, Bay City, Corpus Christi, Texas
Jennings, Harvey, Louisiana

EXPORT OFFICE
74 Trinity Place, New York City

HUNT TOOL COMPANY

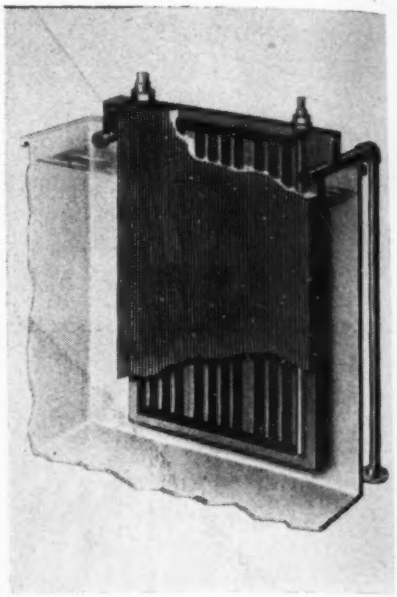
"A BUSINESS BUILT ON SERVICE"

"Karbate" heat exchangers

A new type of heat exchanger, made of "Karbate" chemically inert graphite materials, has been perfected for use in chemical and process industries by National Carbon Company, Inc. Designed specifically for chemical applications, the corrosion resistant "Karbate" heat exchangers possess high heat transfer values and are resistant to practically all acids, alkalis, and solvents. They are unaffected by acute thermal shock and may be used freely in intermittent operations, or in alternately hot and cold chemical baths.

Of plate type, the heat exchangers employ the principle of extended, or corrugated, surface to attain maximum heat transfer area within small over-all size. The compactness of the exchangers increases their inherent mechanical strength. At the same time, it reduces the tank space required for the heaters, further minimizing the hazard of mechanical shock during process operations. As shown in the illustration, the heater is a 4-in. thick plate with a number of internal 1½-in diam. communicating channels for steam or cooling medium.

National Carbon Company standardized production of the heat exchanger units in four design groups, incorporating both parallel and series flow channels, thus making possible 30 different combinations to meet the widest range of heating and cooling requirements. The heaters may be installed in sections, depending upon tank capacity or solution temperatures required, and are suitable for nearly all tank sizes or shapes.

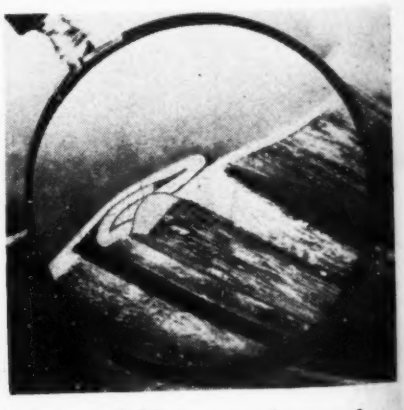


New type heat exchanger.

Prefabricated conduit

Helical corrugated conduit housing for Ric-wiL prefabricated insulated pipe units is now provided with a reinforcing full welded lock seam extending spirally the entire length of each section. Automatic machine weld is made at the factory before galvanizing, assuring a permanently pressure tight, waterproof structure, the manufacturer asserts. Sections are 21 ft. long, completely fabricated with pipe or pipes as specified, insulation and aligning pipe supports. Conduit ends are expanded smooth for a distance of 3 in., removing corrugations to facilitate tight field connection of sections. New drive coupler is adaptable to mechanical or welded closure, with a minimum of field labor.

Ric-wiL prefabricated insulated conduit is available in several types of construction for piping steam, hot water, oil, hot or refrigerated process liquids. Single pipe systems or multiple systems with any specified combination of pipes are tailored to requirements. Any or all of pipes may be individually insulated to required thickness.



Yes sir! AMERICAN HEAVY DUTY ROLLER BEARINGS are made to take all you can give them—and more! Put them to the most abusive, gruelling service you can think of . . . in the heaviest, most powerful equipment built . . . and they'll carry the load smoothly and easily, with minimum maintenance for maximum periods, often outlasting the equipment itself. No wonder AMERICAN HEAVY DUTY ROLLER BEARINGS are specified by most major manufacturers and designers of oil country equipment.

Write today for complete engineering data.

AMERICAN ROLLER BEARING COMPANY
PITTSBURGH, PENNSYLVANIA
Pacific Coast Office: 1718 S. Flower St., Los Angeles, Calif.

AMERICAN ROLLER BEARINGS HEAVY DUTY

AMERICAN
Heavy-Duty ROLLER BEARINGS

The Only Protector with

BIG LIPS

Here's What They Mean To You

The addition of LIPS, a patented feature, to Patterson-Ballagh Protectors has increased the grip by 15%, lengthening the life of both the drill pipe and the Protectors. "Ringing" of drill pipe is now a thing of the past. This exclusive improvement adds streamlining to the mud flow.

Greatly increased velocity of the mud, especially in "slim hole" drilling, where clearances are reduced, have introduced new factors with which casing Protectors must cope. By selecting Patterson-Ballagh Protectors with LIPS, you increase the efficiency of drilling and at no extra cost.

See Composite Catalog

PATTERSON-BALLAGH

Los Angeles 1 • Houston 10 • New York 6

PATTERSON-BALLAGH PROTECTORS
Now made of PBX, synthetic rubber—oil and wear resistant.

PATTERSON-BALLAGH
LIP
PROTECTORS

Heads Union Carbide units

William J. Priestly has been elected president of Electro Metallurgical Company, Electro Metallurgical Company of Canada, Ltd., Michigan Northern Power Company, and Union Carbide Company of Canada, Ltd., units of Union Carbide and Carbon Corporation. Priestley succeeds the late Francis P. Gormely.

W. J. Priestley

Priestly was graduated from Lehigh University in 1908 with a degree in metallurgical engineering, and entered the employ of Bethlehem Steel Corporation. He became superintendent of the armor plate plant and was subsequently division superintendent in charge of all ordnance production for that company. During World War I, he entered Government service and became the civilian head of the Armor Plate and Ordnance Plant erected by the United States Navy. Later, he managed a steel plant making high-grade alloy steels for the automotive industry.

In 1923 Priestly became consulting metallurgist for Electro Metallurgical Company and became vice president in charge of sales development in 1932. He was chief of the alloy steel division of the War Production Board during the period of organization for the expansion of alloy steel production in 1942.

Bethlehem purchases

The Bethlehem Steel Company, through its president, E. G. Grace, announces that it has purchased The American Well and Prospecting Company of Corsicana, Texas, manufacturers of rotary oil well drilling machinery. This company has been in business continuously in Texas for more than half a century and is the originator of the rotary method of drilling. During the last 2 years, the plant has been engaged largely in manufacturing materials on prime war contracts and in recognition of the employees' performance won the Army-Navy "E" Award.

Bethlehem has plans to enlarge the plant and expand its operations to take care of its growing business in the oil country. The Bethlehem Supply Company, another subsidiary of the Bethlehem Steel Company, will market its products to the oil industry.

The general offices of the company will be at 805 East Archer Street, Tulsa, Oklahoma, under the following executive organization: G. A. Tompson, vice president; R. G. Ayers, general manager of sales; A. W. Tarkington, assistant treasurer, and R. G. Petri, auditor and assistant secretary. The plant and office at Corsicana, Texas, will be under the management of J. E. Rittersbacher, who was formerly president of the American Well and Prospecting Company.

Regan representative

Arrangements have been concluded by Tom Regan, president of Regan Forge and Engineering Company, San Pedro, California, appointing the Mid-Continent Supply Company as exclusive representatives in the Mid-Continent area for the entire Regan line of oil field drilling equipment. For several years the supply company has handled Regan products and under the terms of the agreement will now increase the service to cover the entire Mid-Continent.

Regan was in the Mid-Continent for several weeks making arrangements and visiting various fields, returning to the West Coast the middle of July.

Air Filter promotions

The American Air Filter Company Inc., Louisville, Kentucky, announces changes in its organization. W. G. Frank has been made assistant to the president, W. M. Reed. In sales, H. C. Murphy, vice president, has been appointed general sales director; John Hellstrom, vice president, continues as head of the dust control division; Howard W. Pound will be in charge of the air filter division, and Wm. K. Gregory will direct the special products division.

▼ **P. F. Shannon,** newly elected president of the Royalite Oil Company of Calgary, has been appointed a director of the Alberta Petroleum Association.

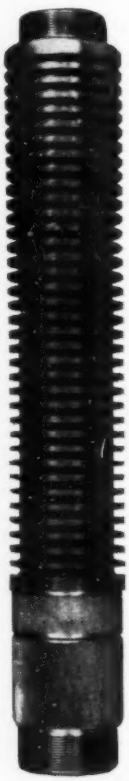
▼ **George A. Weaver,** geologist for Pure Oil Company, has been transferred to Tyler as district geologist for East Texas.

KEEP UPKEEP DOWN
with MARTIN PLUNGERS

No Metal touches the fine finish of your pump tubes. Your pump tubes, therefore, last longer.

No plunger surface is as resistant to abrasion as the Resilient Martin Rings. The plunger will therefore run longer before becoming worn. Only the rings will need replacement.

Insist on Martin Plungers for your Rod pumps to eliminate needless pump repairs and pulling expenses.



3¼" x 36 Groove Martin Plunger Body Without Rings

Write for Illustrated Catalog . . . or See Composite Catalog

SOLD ONLY THROUGH SUPPLY STORES

JOHN N. MARTIN
Manufacturer
11 W. Brady St. Tulsa, Okla.

Field Representatives

Tom Hulett, El Dorado, Ark.
C. J. Baeten, Wichita, Kans.
Lynn C. Holloway, Houston, Texas
Hugh Robinson, Blackwell, Okla.
F. M. Wilson, Wichita Falls, Texas
J. Walter Wade, Chicago, Ill.
E. C. Dilgarde, Casper, Wyoming

Forms own company

D. D. Foster has announced the formation of the D. D. Foster Company, equipment consultants, with offices at 412 Peoples Gas Building, Pittsburgh, Pennsylvania.

D. D. Foster

Foster, who is a graduate of Carnegie Institute of Technology, was previously connected with the Pittsburgh Equitable Meter Company—Merco Nordstrom Valve Company for 15 years, first as district manager and more recently as acting general sales manager.

This company will handle the engineering sales of specialized equipment for the oil, gas, and chemical process industries in Pennsylvania, Ohio, and West Virginia. A. H. Stroyd is an associate in the firm.

Atkins resigns

Terminating an association of nearly 15 years, Earle R. Atkins has resigned as vice president and sales manager of Chiksan Tool Company, Brea, California. During the period in which Atkins directed Chiksan sales, the company's annual volume has grown from $250,000 to more than $2,500,000. From a sales force of two men, covering Southern California, Atkins developed a selling organization of 40, with representatives in principal cities throughout the United States. In addition, a permanent branch was established in New York City and distribution was arranged through leading jobbers of industrial equipment. Under his direction, Chiksan products have become well known and widely used throughout this country and in many foreign countries. His immediate plans call for a much-needed rest, after which he plans to resume his successful career in the field of sales management.

Back with Tube Turns

Wilbur E. Geiser, who has been on loan for the last eight months to the scheduling department of the War Production Board's valve and fittings section, with headquarters in Washington, has returned to his post as manager of the Philadelphia office of Tube Turns, Inc., Broad Street Station Building.

Wanted—Petroleum Engineers and Geologists

...with field experience. Excellent opportunity with major oil company operating in Venezuela. Permanent positions. Engineers should be experienced in well completion practice and equipment. Mud control experience valuable. Give age, educational background, experience and marital status to Box 17, % The Petroleum Engineer, P. O. Box 1589, Dallas, Texas.

Named directors

Hunter Michaels, sales manager, Railway Steel Spring Division and Hugh Corrough, division manager of Alco Products of American Locomotive Company have both been named directors of their respective divisions.

Hunter Michaels

Hugh Corrough

Michaels has been with the company since 1927. Prior to that time he was connected with the National Dump Car Company, the American Car and Foundry Company, the Hart-Otis Company, Rodger Ballast Car Company, Union Metal Products Company, and the Railway Steel-Spring Company.

Corrough has been with Alco Products division of the company since June, 1936, and served in the capacities of chief mechanical engineer, assistant manager of engineering, manager of engineering, and manager of Alco.

"CLEVELANDS"

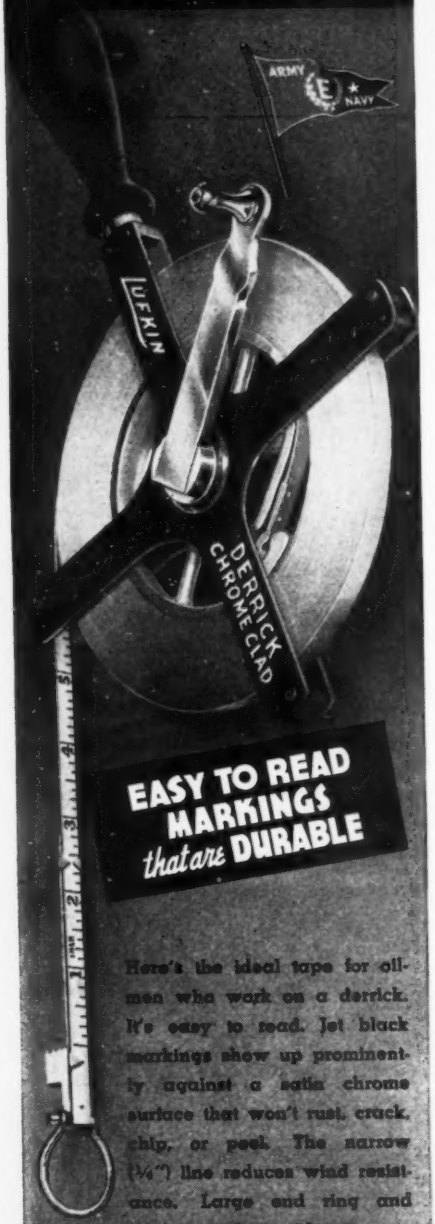
Taking the Tough Jobs in Stride is a Proved CLEVELAND Characteristic

For more than twenty years "CLEVELANDS" have been put to the toughest tests on hundreds of ditching jobs in all sort of soils and over the roughest terrain, and have continuously, according to the record, delivered maximum performance. ● Contributing to "CLEVELANDS" ability to deliver maximum performance under normal or emergency conditions are these features: Multi-Speed Transmission—Abundant Power—Operating Ease—Maximum Maneuverability—High Capacity Digging Wheel—Balanced Design—Unit Type Construction—Top Quality Material.

THE CLEVELAND TRENCHER COMPANY
20100 ST. CLAIR AVE "Pioneer of the Small Trencher" CLEVELAND 17, OHIO
"CLEVELANDS" Save More...Because they Do More

LUFKIN

"DERRICK" CHROME CLAD STEEL TAPES



EASY TO READ MARKINGS *that are* DURABLE

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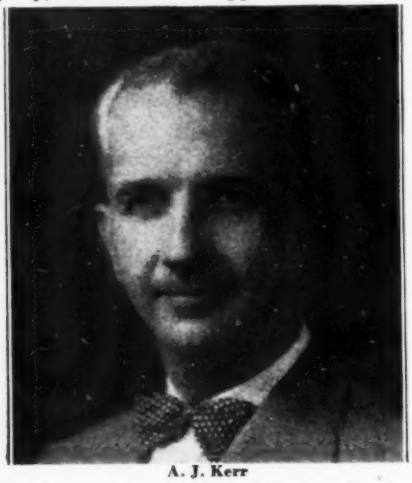
LUFKIN

SAGINAW, MICHIGAN • New York City

TAPES • RULES • PRECISION TOOLS

Kerr Appointed

Colonel Willard F. Rockwell, president of the Pittsburgh Equitable Meter Company-Merco Nordstrom Valve Company, announces the appointment of A. J. Kerr to the position of general sales manager for the combined organizations. Kerr, a veteran of 20 years with the company, was district manager of the firm's Midwest headquarters at Tulsa, Oklahoma, prior to his Pittsburgh home office appointment.



A. J. Kerr

A graduate of Carnegie Institute of Technology with a B.S. degree in mechanical engineering, Kerr was appointed district manager of the Equitable Meter Company's Tulsa office in 1925, prior to the merger of the Pittsburgh Meter Company and the Equitable Meter Company in 1926.

M. D. Gilbert

Kerr's first official act as sales manager was to appoint M. D. Gilbert as district manager of the Tulsa office, C. K. Madison as district manager of the Houston, Texas, office, and W. S. Andrews as district manager of the Pittsburgh office. Gilbert and Madison formerly served as service engineers in the Midwest territory, which includes the states of Arkansas, Louisiana, New Mexico, Texas, and Oklahoma. Andrews, formerly a service engineer out of Pittsburgh, has more recently traveled the state of Ohio for the company, out of Cleveland.

C. K. Madison

W. S. Andrews

Hill Hubbell promotions

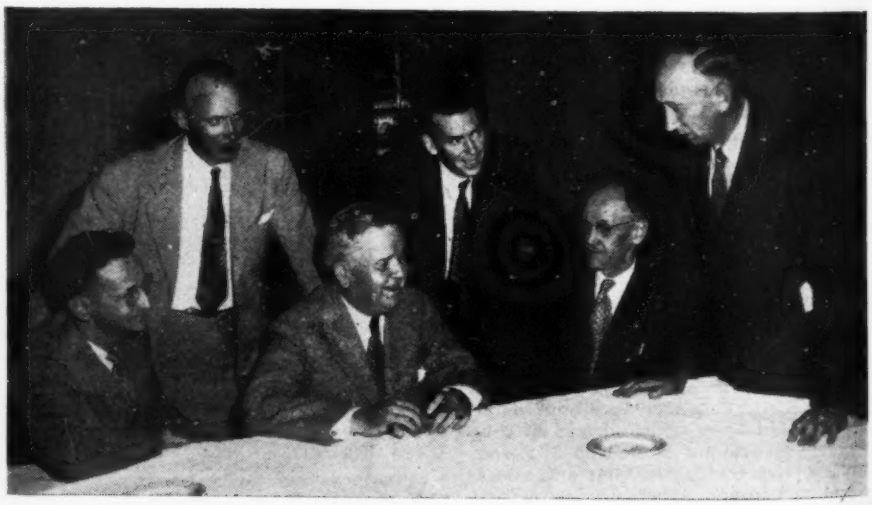
Milton M. Bowen of Chicago, Illinois, has been appointed vice president of General Paint Corporation and manager of the eastern division in charge of pipe wrapping. Bowen was previously special representative of the Hill Hubbell and Company Division of General Paint Corporation, and has been with them since 1936. He is making his headquarters at the Cleveland office of the company at 3091 Mayfield Road, Cleveland 18, Ohio.

Jack Morain, formerly general superintendent, has been promoted to production manager in charge of operations. Morain has been with the company since 1926 and is responsible for a great deal of the design and development of equipment.

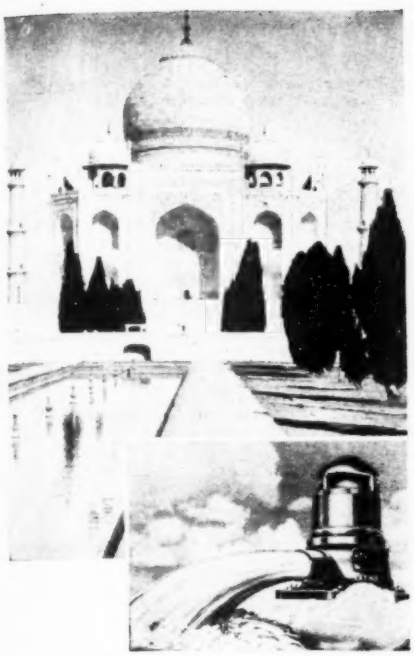
The office in Cleveland will be in charge of Miss Frances Tuhey, who has served in various capacities since 1936 and who has been promoted to assistant to the division manager.

The Southwest territory will continue to be served by R. A. (Bob) McCarthy, special representative, whose headquarters are in Dallas, Texas.

Compact engineering committee



This photograph of the engineering committee of the Interstate Oil Compact Commission was taken at the Denver, Colorado meeting. They are, left to right, J. F. Gallie, El Dorado, Arkansas; Dean W. H. Carson, Norman, Oklahoma; Dr. E. L. DeGolyer, Dallas, Texas; John M. Kelly, Santa Fe, New Mexico; Dr. Eugene Stephenson, Lawrence, Kansas, and Dr. F. M. Van Tuyl, Golden, Colorado.



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Each Layne Water System is a "tailored to fit" job. The size of motor, casing, shafting, bearings, pump bowls and screen mesh are determined by the actual physical and operating conditions of each installation.

The finished product is delivered—"in operation"—producing the stipulated quantity of water. Layne Companies are located throughout the territory served. This insures prompt and efficient attention when adjustments, servicing or repairs are required.

For literature, catalogs, etc., address Layne & Bowler, Inc., General Offices, Memphis 8, Tenn.

AFFILIATED COMPANIES: Layne-Arkansas Co., Stuttgart, Ark. * Layne-Atlantic Co., Norfolk, Va. * Layne-Central Co., Memphis, Tenn. * Layne-Northern Co., Mishawaka, Ind. * Layne-Louisiana Co., Lake Charles, La. * Louisiana Well Co., Monroe, La. * Layne-New York Co., New York City * Layne-Northwest Co., Milwaukee, Wis. * Layne-Ohio Co., Columbus, Ohio * Layne-Texas Co., Houston, Texas * Layne-Western Co., Kansas City, Mo. * Layne-Western Co. of Minnesota, Minneapolis, Minn. * International Water Supply Ltd., London, Ontario, Canada

LAYNE
WELL WATER SYSTEMS
DEEP WELL PUMPS
BUILDERS OF WELL WATER SYSTEMS FOR INDUSTRIES AND MUNICIPALITIES

Hycar service engineer

Frank E. Bell has been appointed technical service engineer for Hycar Chemical Company, producer of synthetic rubber from butadiene, it was announced by Frank M. Andrews, general sales manager.

F. E. Bell

Bell, who has had 13 years' experience in the rubber industry, comes to Hycar from the Barrett division of Allied Chemical and Dye where he was employed 4 years as technical service representative. Prior to that time he was with the Bolta Corporation, Johnson Rubber Company, and Aetna Rubber Co.

Made Graver vice president

E. N. Gosselin, president of Graver Tank and Manufacturing Company, Inc., East Chicago, Indiana, announces the election by the board of directors at their annual meeting of J. E. Swanson as a vice president of the company.

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Swanson, who has been with the company for more than 25 years, has served in various executive capacities for the organization, having most recently held the position of general manager of sales. His election as a vice president of Graver will be of interest to his many friends and associates throughout the entire steel, chemical, and petroleum industries.

Named manager

K. R. Van Tassel has been named manager of the industrial control division of General Electric's industrial division, it is announced by J. E. N. Hume, commercial vice president. Van Tassel succeeds George R. Prout, recently appointed manager of the company's air conditioning and refrigeration division of the appliance and merchandise department.

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Say "DOUBLE E" WHEN YOU WANT .... The Best

TUBING CATCHER

The outstanding advantage of the DOUBLE E Multiple Step Tubing Catcher is that it protects the tubing without distorting the casing. This is accomplished by the multiple step design, which permits an extra large gripping surface, distributing the load over a much greater area than other catchers. Note the illustration at left. The simplicity of design and the heavily sectioned parts of this tubing catcher naturally are points of importance in providing long and economical life.

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DALLAS 9, TEXAS

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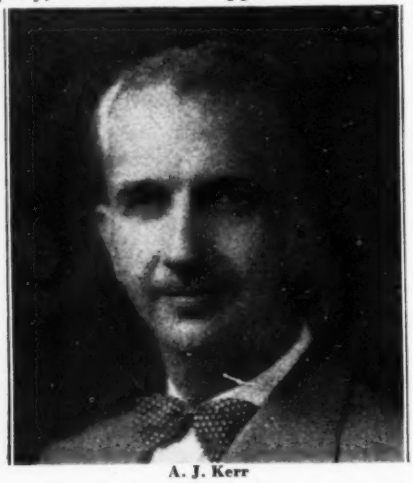

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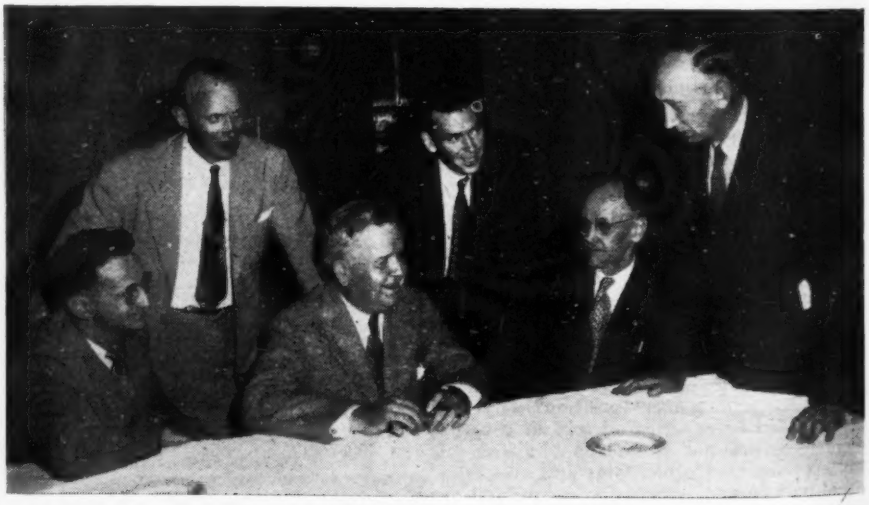

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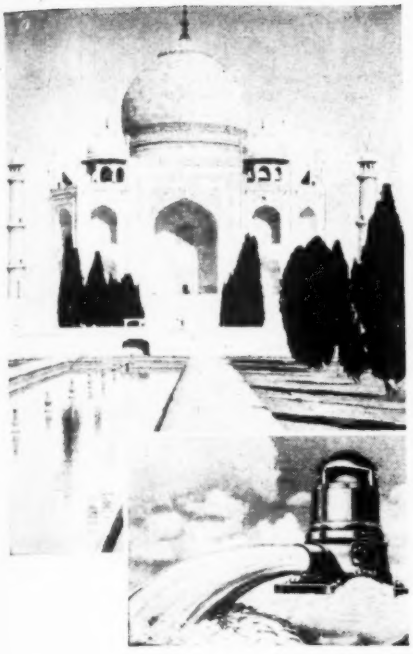

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EQUIPMENT ENGINEERS
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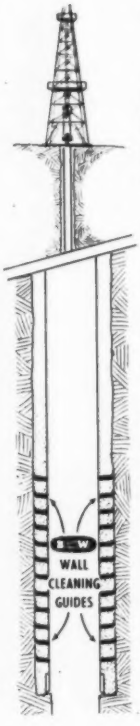
Prevent CRATERING by using

B and W, Inc.

Wall Cleaning Guides

ON YOUR

SURFACE CASING



1 TO PREVENT BLOW-OUTS

Wall Cleaning Guides placed on the bottom joints of surface casing project against blow-outs around the casing, or cratering from an imperfect cement job.

2 TO PREVENT BACKING OFF

The rotation and jarring of the drill pipe tends to loosen the threads of the bottom joint of surface casing, particularly opposite an imperfect cement job. The unscrewing of this joint may result in an impossible fishing job, or abandonment.

Wall Cleaning Guides placed on the bottom joints will assist in securing a *perfect* cement job, which in turn will securely anchor the casing to the formation.

Table of Dimensions

Casing Size	Hole Diameter	Outside Wire Diam.
8⅝"	12¼"	14½"
9⅝"	12¼"	14½"
10¾"	14¾"	16¾"
13⅜"	17¼"	18½"

BRUCE BARKIS — B and W, Inc. — KENNETH WRIGHT

Well Completion Specialists

WEST COAST: 3545 Cedar Avenue
Long Beach, Calif. • Phone: L. B. 4-8366
GULF COAST: 305 M & M Building
Houston, Texas • Phone: Preston 9783

Book Reviews

Oil and Petroleum Year Book 1944, *Walter E. Skinner, 20, Copthall Avenue, London, E. C. 2. Price, 12S 6d. Pages, 180.*

This thirty-fifth annual edition of the Oil and Petroleum Year Book contains particulars of 537 companies engaged in all branches of the industry and a list of 216 names and addresses of managers, engineers, and the companies with which they are connected. The Year Book describes problems of supplying the forces of the United Nations operating in Europe and elsewhere: various pipe-line projects that were completed during the year, the use of inland waterway transportation, and progress in chemical research.

Hydrocarbons of the Uinta Basin of Utah and Colorado, *by Clark F. Barb and James Ogden Ball, Quarterly of the Colorado School of Mines, Golden, Colorado. Pages. 115. Price, $1.50.*

This book includes treatments of two phases of the subject of hydrocarbons of the Uinta Basin, "Review of Geology and Field Work" and "Survey of Bitumen Analyses and Extraction Methods." The first part by Professor Barb has considerable material resulting from his recent work in the basin, together with a discussion of past field work.

The second part, by Professor Ball, surveys the bitumen analyses and extraction methods of past research, and explains the methods and results of research that he has conducted in the past several years. Graphic presentations by both authors add to the value of the book.

A Dictionary of Abbreviations, *by Herbert John Stephenson, The MacMillan Company, New York, N. Y. Pages, 126. Price, $1.75.*

Listed both alphabetically and according to subject matter, J. H. Stephenson's book contains the many different abbreviations that business people, writers, scholars, and laymen need to use. The abbreviations are assembled from numerous separate lists covering a wide range. It is useful for offices where technical information is used.

Practical Design Handbook, *by Dr. Alois Cibulka, Clark and Courts, 1210 West Clay, Houston 1, Texas. Pages, 32. Price, $1.*

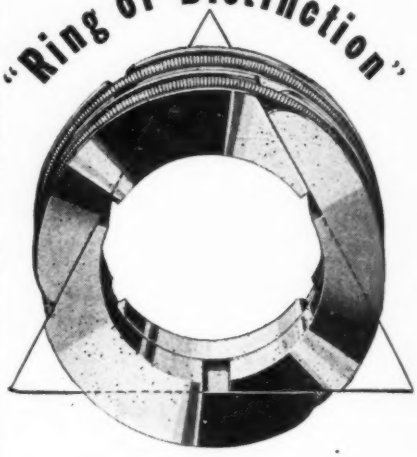
Dr. Cibulka is author of Practical Design Handbook for Engineers, a more complete work on the subject than this latest work, of Calculus for Practical Engineers, and Refining Piping Design. "RST," or Reinforced Steel Timber, an invention of the writer, is discussed in the new volume in its relation to various structures. This is amplified with diagrams and tables.

WANTED: Mechanical engineer for development and research work on oil country sucker rods. Must be capable of selecting and designing equipment for physical research laboratory. An excellent opportunity to become associated with a progressive company which is open to ideas for improving sucker rods. Work will include fields of forging, induction heating, photoelasticity, metallurgy, and fatigue testing. An excellent opportunity to gain experience in each of these fields. Applicant must be 28 years of age or older. Please submit application in writing giving detailed description of your experience and expected salary. Must have U. S. E. S. referral card.

Texasteel Manufacturing Company
3909 Hemphill Fort Worth, Texas

FOR THE DEFENSE OF DEMOCRACY
THE BEST IS NONE TOO GOOD

FRANCE PACKING has a "Ring of Distinction"



Imitated but never duplicated, the France ring is manufactured in three sections. The contacting faces form the lines of an equilateral triangle. As the ring is expanded or contracted, the sections must move in or out radially equal distances from the center of the rod to which the ring is fitted. This fundamental mechanical principle accounts for the efficiency, trouble-free performance and extra-long life of France Metal Packing.

After years of service, when the rings have become worn to such an extent that the sections nearly butt together, further years of additional service can be obtained by cutting off the narrow points of the three sections where they form a part of the inner circumference of the ring. The spring then requires adjustment so that the sections are held to the rod with a slight tension.

For installation in engines, pumps and compressors—under all conditions of service, France Full-floating Metal Packing means true economy in the long run.

Permit France Engineers to analyze your packing requirements.

Write for Catalog M-3

ORIGINAL FRANCE METAL PACKING
Sold on approval
Satisfaction Guaranteed

THE FRANCE PACKING COMPANY
Tacony Philadelphia 35 Penna.
Mid-Continent Representative:
MR. J. M. FULLER, 3725 West 7th Street
FORT WORTH, TEXAS

Original FRANCE METAL PACKING

Talon, Inc., promotes

Talon, Inc., Steel Tube Division, Oil City, Pennsylvania, announces following personnel changes:

Robert A. Campbell, sales manager, has been appointed general manager. He will continue to direct the sales activities in addition to his new duties. John Farrimond has been named superintendent of finishing departments.

E. H. Lunken passes

Edmund H. Lunken, chairman of the board of The Lunkenheimer Company, Cincinnati, Ohio, valve manufacturers, died recently at his summer home in Michigan, as the result of a cerebral hemorrhage.

Lunken, who was 83 years old, had been active and in good health until last winter, when he suffered an attack of influenza.

The son of Frederick Lunkenheimer, founder of The Lunkenheimer Company, he was born in Cincinnati and educated in the Cincinnati schools. At the age of 16 he entered his father's business, which had been established in 1862. Upon the death of his father in 1889, he assumed leadership of the company and remained its senior officer until his death. In 1892, he legally changed his surname to Lunken, but did not change the name of the company.

Appoints distributor

Continental Motors Corporation, Muskegon, Michigan, announces the appointment of the Iverson Tool Company, Tulsa, Oklahoma, as a distributor of Continental Red Seal engines. The Iverson Tool Company has branches in Oklahoma City, and Okmulgee, Oklahoma; Artesia, New Mexico; Borger, Odessa, and Wink, Texas, and Salem, Illinois.

To U.S. Air Force

Transferring his responsibilities from the oil fields to the air fields, Frank Wheatley, Jr., is in the U. S. Army Air Corps, stationed at Sheppard Field, Texas.

He had been associated with Frank Wheatley Pump and Valve Mfr. since 1938, and was vice president and general manager when he entered the service.

Pioneers in the manufacture of pipeline and pumping equipment, the Wheatley organization was sub-contractor on the Sydney S. Smith portable pipe line, now doing "military service" with the armed forces in foreign fields. It is also prime contractor on special equipment for the U. S. Navy and has been almost since Pearl Harbor.

New export address

Recent announcement was made of a change in address of the export oil field division of The Buda Company. The new location is 253 West 64th Street, New York City. This division has charge of all export sales of the complete line of Buda oil field engines and parts.

LUNKENHEIMER VALVES *Spell* "Low Maintenance"

Fig. 16
"Renewo" Globe

Long service life and low maintenance have ever been the goal of Lunkenheimer design. Ask users why they prefer Lunkenheimer Valves and their answer is universal—"they're built to last and give the least amount of trouble."

These staying qualities are particularly important when production is running at previously unheard-of tempos — when "time out" is figured in loss of vitally needed equipment, rather than mere dollars. Lunkenheimer Valves are helping many a maintenance crew do a better job.

Illustrated are just a few of the many types of valves in the Lunkenheimer line —bronze, iron, steel and corrosion-resistant alloys—for all prevailing pressures and temperatures.

Your Lunkenheimer distributor is always ready to help you with your maintenance, repair and operating problems. His facilities are at your call.

Fig. 1640
"King-clip" Gate

Fig. 2125
Bronze Gate

ESTABLISHED 1862
THE LUNKENHEIMER CO.
—"QUALITY"—
CINCINNATI 14, OHIO, U. S. A.
NEW YORK 13 CHICAGO 6
BOSTON 10 PHILADELPHIA 7
EXPORT DEPT. 318-322 HUDSON ST., NEW YORK 13, N. Y.

Fig. 1430
Iron Body Gate

Fig. 1938
Steel Gate

Fig. 123
"N-M-D" Globe
(Non-Metallic Disc)

BRONZE, IRON, STEEL AND CORROSION RESISTANT ALLOY VALVES, 125 TO 2500 LB. S.P.;
BOILER MOUNTINGS, LUBRICATING DEVICES, AIRCRAFT FITTINGS

★ ★ ★ ★ ★ ★ ★

GUARANTEED

Safe and Effective

to Remove and prevent boiler scale and corrosion while your equipment operates.

"The Entirely Different Boiler and Engine Treatment"

SAND-BANUM

Unconditional Guarantee

Try it entirely at our risk for 30, 60 or 90 days. It must perform to your entire satisfaction or you owe us nothing. No money in advance; not even shipping charges.

AMERICAN SAND-BANUM COMPANY, Inc.

9 Rockefeller Plaza, New York City 20

Stocks carried by
WESTERN SAND-BANUM COMPANY
Houston, Texas
and at other convenient points including leading supply houses

Export Representatives
PETROLEUM MACHINERY CORP.
30 Rockefeller Plaza New York City 20

The simplest gas mixing valve built. Thousands in use on pumping wells throughout the oil fields. Increased allotments of material will make them available to supply all demands in the near future.

J. & S. CARBURETOR CO.

2634 North Beckley

DALLAS 2, TEXAS

We have prepared a 15 page study of

Panhandle Eastern Pipe Line Co.

Common Stock

Under the "Mokan Plan" recently approved by stockholders, 163,710 shares of the above stock are being offered under rights to stockholders of

Missouri Kansas Pipe Line Company

Subsequently, upon liquidation of Mokan's secured debt, an additional 363,802 shares of Panhandle stock are to be offered in exchange to Mokan stockholders.

A copy of our analysis will be mailed upon request.

KIDDER, PEABODY & CO.

FOUNDED 1865

Members New York Stock and New York Curb Exchanges

NEW YORK
17 WALL STREET

BOSTON
115 DEVONSHIRE ST.

PHILADELPHIA CHICAGO

New firm organized

W. R. Coleman has resigned as sales manager and treasurer of Engineering Laboratories, Inc., and joined Marvin E. Morrow, Chester L. Sharp, and John W. Wade, in the organization of the Coleman Instrument and Manufacturing Company with headquarters and plant in Tulsa, Oklahoma.

W. R. Coleman

He announced the firm will specialize in precision machine work, electrical engineering and development, and precision instrument manufacturing.

Morrow resigned from the Carter Oil Company where he has been in geophysical laboratory work for the last 10 years. Sharp, long associated with the geophysical industry in the Mid-Continent area, is widely known as a master tool and die maker and precision machinist. Wade has a long record of experience in the manufacture and servicing of geophysical equipment.

Headquarters of the new company are at 716 South Troost, Tulsa.

To direct purchases

Stanley W. MacKenzie has been appointed director of purchases of United States Rubber Company to succeed George M. Tisdale, recently elected a vice president and member of the executive committee of the company.

On leaving the army in December, 1918, MacKenzie became connected with the tire business as a salesman in Des Moines, Iowa. Two years later he returned East and joined the United States Rubber Company organization in New Haven. In 1932 he became purchasing agent of the mechanical division at Passaic. Eight years later his duties were enlarged to include supervision of purchasing and inventory control at such plants as Bristol, Providence, and Sandy Hook.

MacKenzie was made assistant to the director of purchases in 1941, which position he held until his present promotion.

Sam Bowen dies

Sam Bowen of S. R. Bowen Company, Huntington Beach, California, died August 6. He had been inactive in the firm for the last two years due to poor health.

Bowen entered the petroleum industry in 1900 with the Oil Well Supply Company. In 1910 he went into business for himself at Coalinga, principally in service work, and in 1913 began the manufacture of tools. He sold out in 1917 and went into the army. In 1921 he opened a shop at Huntington Beach for the manufacture of tools and for service work.

Bowen was one of the charter members of Nomads and helped with the organization of that body.

Beardsley retires

H. I. "Hi" Beardsley, veteran executive in the sales department of Pittsburgh Equitable Meter Company, has announced his early intentions of retirement from active business. "Hi," who numbers his friends by the thousands in the petroleum and public utility fields, has had an active and productive career with the Pittsburgh organization dating from his original employment as a water meter salesman on July 1, 1912.

H. I. Beardsley

For many years he traveled the New York and New England territory for the old Pittsburgh Meter Company, predecessor to the present organization. From 1918 to 1930, he was district manager in the Chicago territory, which position he relinquished to head the newly established gasoline and oil meter division.

Beardsley, for the present, will remain active in company affairs and lend his assistance to H. D. Leisenring, who has been appointed as his successor. Leisenring, an engineering graduate of Lafayette College, brings to his new position a background of experience gained through 10 years of exclusive work with the oil companies in the midwest. He formerly had charge of this branch of Pittsburgh Equitable products in the Chicago territory and will now make his headquarters in the main offices at Pittsburgh.

H. D. Leisenring

Wins extra stars

Tube Turns, Inc., Louisville, Kentucky, has been honored with extra stars for both its Army-Navy "E" pennant and Maritime "M" burgee. Al ben W. Barkley, majority leader of the United States Senate, presented the awards on behalf of Robert P. Patterson, Undersecretary of War. It was Tube Turns' second "E" star and the second star added to the company's "M."

Rogers appointed

Mixing Equipment of Rochester, New York, manufacturer of Lightnin and Mixco mixers, announces the appointment of Edgar A. Rogers as exclusive representative in Georgia, Alabama, and the major portion of Tennessee.

Having been engaged in consulting and sales work in the chemical and process industries in this territory for many years, Rogers enjoys a wide acquaintance among manufacturers and engineers. He will make his headquarters in the Chattanooga Bank Building, Chattanooga, Tennessee.

. . . IF YOU ARE INTERESTED IN SEAMLESS AND DROP FORGED STEEL PRODUCTS

Anticipating every practical calculation or analysis that may confront you, the buyer of Seamless and Drop Forged Steel Products, The Harrisburg Steel Corporation has compiled this Catalog to serve with the same efficiency and accuracy that you have found in all Harrisburg Products.

Indexed, glossarized and departmentalized, it is a veritable textbook for expert or apprentice. Tables of authentic S. A. E. specifications covering every product we make in whatever grade or quality you may need.

A quick-reference dictionary of our products, their ingredients and uses completes this handbook, which gives accurately illustrated descriptions of Harrisburg Products.

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HARRISBURG, PENNSYLVANIA

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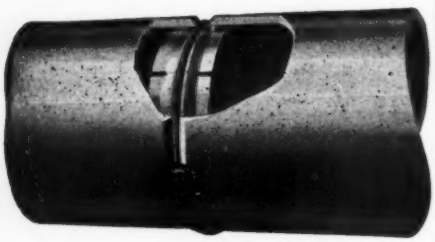
Company _____

Address _____

HARRISBURG *Seamless* STEEL PRODUCTS

Use
WEDGE
Split CHILL RINGS
AND WITHSTAND
SHOCK
STRAIN and
VIBRATION

A welded pipe line is no stronger than its weakest point—at one time joints were the weakest point but NOW by using WEDGE Chill Rings with the Patented SPLIT Feature the joints are the STRONGEST part of the line. In case of shock, strain or vibration the pipe will fail before the REINFORCED joints. Because WEDGE Chill Rings have proven so successful they are used on Victory Ships for welding pipe. It is imperative that all welded joints are the strongest obtainable. WEDGE Chill Rings are especially adaptable for refinery or pipe lines. They enable you to weld FASTER and BETTER—saving time and money. It will pay to investigate.



Write for Information

WEDGE PROTECTORS, INC.
9522 Richmond Ave., Clevealnd 5, Ohio

WEDGE
Split CHILL RINGS
SAVE MONEY

New manager sales

Norman W. Stirling, formerly of the M. W. Kellogg Company, New York, has been appointed manager of sales for the Whitlock Manufacturing Company, Hartford, Connecticut, manufacturers of heat transfer equipment.

In 1917, shortly after his graduation from Buchtel College, Stirling was appointed to the U. S. Naval Academy. He was transferred to the U. S. Navy Steam Engineering School at Stevens Institute. After receiving his commission he spent some time at sea, and later studied turbine electric drive at the University of Pittsburgh.

In 1922 he received his discharge from the Navy and worked with his brother in the Stirling Machine and Boiler Company until 1928 when the company was dissolved. He then joined the M. W. Kellogg Company, New York, and was with that organization until his recent appointment at Whitlock.

Visits New York

Lou Bronzan of Baash-Ross Tool Company, Los Angeles, California, was in New York making business calls early in the month.

New division managers

The Axelson Manufacturing Company, Los Angeles, California, announces through General Sales Manager Alvin "Dutch" Zwerneman, the permanent appointment of K. S. Ramey and J. R. Walker to the management of the California and Mid-Continent sales divisions, respectively. These appointments have been held by Ramey and Walker for some time on a temporary basis, pending this confirmation.

Alvin Zwerneman

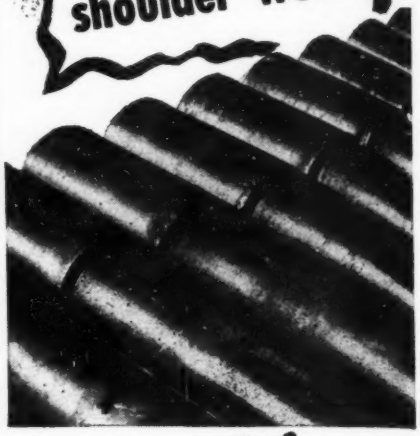
Ken Ramey, who started with the Axelson sales department at Coalinga in 1923, handled the Santa Fe Springs district until a year ago when he became temporary California sales manager. Ramey's confirmation comes as a well deserved reward for 21 years' service in the interests of Axelson's petroleum equipment.

K. S. Ramey

J. R. Walker

Also joining the Axelson organization in 1923, Jeff Walker has gained wide experience in California, Rocky Mountain, Eastern, and Mid-Continent sales divisions of Axelson.

Tube Borium
HALTS
shoulder wear



Doubles
tool joint life

For fifteen years Tube Borium has been used on drilling bits to increase cutting speeds and drill more out-to-gauge hole. Now you can use this same alloy to greatly prolong the life of your tool joints!

An exceedingly small quantity of Tube Borium welded in a ring around the shoulder not only doubles tool joint life—even under the toughest operating conditions—but maintains over all joint strength and correct elevator contour. Applications are economically made on both new and resleeved joints.

APPLICATION: Accepted method of application is to under-cut new or resleeved joints at the shoulder to form a recess ⅛" deep by 1½" wide. The recess is then filled by welding in with ⅜" Electric Tube Borium to form the wear resistant inlay.

Write for this special Stoody engineering bulletin describing in detail hard-facing procedures on tool joints—no obligation.

STOODY COMPANY
1142 WEST SLAUSON, WHITTIER, CALIF.

STOODY HARD-FACING ALLOYS
Retard wear... Save Repair

G-E Appointments

Three appointments in General Electric's motor division have been announced by W. H. Henry, manager of the division.

Elliott Harrington has been named manager sales of a newly formed integral-horsepower, alternating-current motor section, located in Schenectady, which includes all such induction motors now manufactured in the Lynn, Schenectady, and Oakland Works.

J. T. Farrell has been named manager sales of the newly formed integral-horsepower direct-current motor section, also in Schenectady, with commercial responsibility for all such motors and generators now made in the company's Lynn, Erie, and Fort Wayne plants.

D. A. Yates has been appointed assistant manager sales of both sections in charge of Lynn motor sales group, and will be located at the Lynn, Massachusetts, River Works.

Harrington for the last 2½ years has been manager sales of Schenectady induction motors.

Farrell was placed in charge of the direct-current motor group in 1936, which position he has held until his present appointment. Yates was associated with the machinery manufacturing section from June, 1931, to June, 1932, when he was transferred to the motor division. There he was assigned to handle single-phase motor business until he was placed in charge of Lynn motors in November, 1942.

President Haynes Stellite

E. E. LeVan has been selected president of Haynes Stellite Company, a unit of Union Carbide and Carbon Corporation, succeeding the late Francis P. Gormely.

E. E. LeVan

LeVan was graduated from Pennsylvania State College in 1917, with a degree in mechanical engineering. After spending 5 years as a mechanical engineer with Bethlehem Steel Company, he entered the employ of Haynes Stellite Company as a sales engineer in 1922, becoming chief engineer 3 years later. In 1927 LeVan entered the sales department, and in 1929 became general sales manager. He was elected vice president in 1939, and on May 22, 1944, was made vice president and general manager, and a director of Haynes Stellite Company.

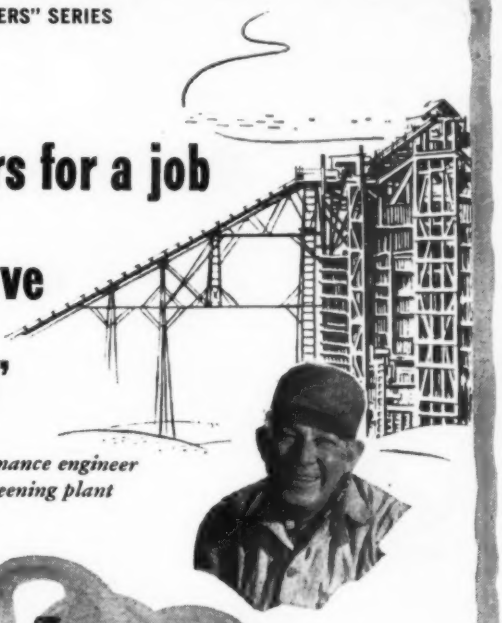
Publish house organ

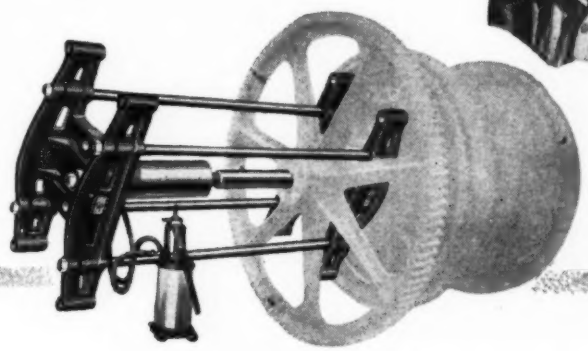
Clark Bros. Company, Inc., has initiated a new house organ for its employees. The first issue is an attractive 16-page edition with the cover in color and is profusely illustrated. John L. York, advertising manager of the company, is editor. After a contest the magazine has been named "The Clark Angle."

NO. 17 OF A "READY-WITH-A-RODGERS" SERIES

"...only 2 hours for a job that would have taken a week"

—as reported by the maintenance engineer of a Minnesota gravel screening plant





Uses for the

RODGERS UNIVERSAL HYDRAULIC PRESS

- Gear Pulling
- Wheel Press Work
- Jacking Pipe or Tile
- Erecting Machinery
- Relocating Machinery
- All-Purpose Jack

HYDRAULICS Rodgers KEEP THE WORLD MOVING

THE PROBLEM . . . replacing the gear and straightening a drum shaft installed in a tower approximately 150 feet high where 120 tons pressure was required.

"With the Rodgers Universal Hydraulic Press, we moved in, pulled the gear and straightened the shaft and replaced the gear in two hours' time, *right on the spot.* Such a job as this would have meant building a scaffold, dismantling the equipment and lowering it to the ground to be taken to a repair shop, then hoisting it back again for reassembly. With our Rodgers portable press, we saved practically a full week's complete shutdown, right at the peak of our production."

RODGERS UNIVERSAL HYDRAULIC PRESSES can be used in any place and in any position where pulling, pressing or lifting power is needed. Tremendously powerful, yet portable—they can be carried to the job and assembled around the work. Be ready with your Rodgers—when the emergency comes! If it's a Rodgers, it's the *best* in Hydraulics.

4 SIZES... one for *your* job... write today for full information!

Rodgers **HYDRAULIC, INC.**

St. Louis Park, Minneapolis 16, Minnesota

LEADING CONTRACTORS PREFER
Sterling
PUMPS • HOISTS • LIGHT PLANTS
DEPENDABLE
RUGGED
SIMPLE
•
SAVE
MONEY
SAVE
TIME
EASY
TO
OPERATE
•
WRITE
FOR
CATALOG
STERLING QUALITY
STERLING
MACHINERY CORPORATION
405-13 SOUTHWEST BLVD. KANSAS CITY 10, MO.

New president C.N.G.A.

The annual meeting of the board of directors of California Natural Gasoline Association was held July 11, at the Biltmore Hotel, Los Angeles. This was the occasion for the formal transfer of leadership of the association to C. D. Gard, Union Oil Company of California, by R. W. Heath, Signal Oil and Gas Company, retiring president.

C. D. Gard

Gard joined C.N.G.A. within two months of its organization in June, 1926, and has served as its technical committee chairman, a director and member of the executive committee, and as vice-president.

Election of M. L. Arnold, Richfield Oil Corporation, as vice president, was also announced at the meeting. The following are officers, directors, and members of the executive committee for 1944-1945:

President, C. D. Gard*; vice president, M. L. Arnold*; A. H. Bell, Continental Oil Company; A. H. Bradford, West Coast Refining Company; J. A. Campbell, J. A. Campbell Company; L. V. Cassaday*, Lomita Gasoline Company; F. J. Colton*, Tidewater Associated Oil Company; F. E. Coyle, Tide Water Associated Oil Company; D. A. Cushman, O. C. Field Gasoline Corporation; W. C. Dayhuff*, California Research Corporation; F. F. Coyle, Pacific Gas and Electric Company; H. L. Eggleston, Gilmore Oil Company; O. C. Field*, O. C. Field Gasoline Corporation; J. S. Fluor, Jr.*, The Fluor Corporation, Ltd., M. L. Fort, Pacific Lighting Corporation; R. E. Foss**, Barnsdall Oil Company; I. B. Funk, Cowan Oil and Refining Company; R. D. Gibbs*, Union Oil Company of California; R. W. Heath*, Signal Oil and Gas Company; A. K. Hegeman**, Clark Bros. Co., Inc.; John C. Herron, Shell Oil Company, Inc.; W. A. Kirk*, California Southern Oil Company; W. H. Kraft*, Honolulu Oil Corporation; H. R. Linhoff*, Richfield Oil Corporation; R. S. Lytle, Los Nietos Petroleum and Refining Company; S. F. Magor. The Superior Oil Company; P. S. Magruder*, General Petroleum Corporation; G. C. McLaren*, Standard Oil Corporation; E. W. McAllister**, Western Gulf Oil Company; William Moeller, Jr.*, Southern California Gas Company; H. E. Moulton*, C. C. M. O. Company; N. H. Mull*, The Texas Company; H. W. Parmelee, Del Valle Gasoline Company; H. M. Paulsen, Bankline-Norwalk Company; W. L. Rifenberick, Industrial Engineers, Inc.; W. W. Robinson, Jr.*, The Texas Company; W. N. Roper, Western States Gasoline Corporation; J. H. Sargent, Kettleman North Dome Association; W. D. Smith, Wilshire Oil Company; George Sowards**, The Ohio Oil Company; T. L. Taggart*, Standard Oil Company; J. B. Taylor*, Signal Oil and Gas Company; R. S. Tulin*, Shell Oil Company, Inc.; J. B. Wharton, Belridge Oil Company; R. C. Wheeler*, General Petroleum Corporation; D. M. Wolfe**, Standard Oil Company; R. W. Garman (executive committee only), and George L. Tyler, secretary-treasurer.

*Member executive committee and director.
**New director.

LET JOHN FIELD-MAN HELP YOU SOLVE YOUR NEXT WATER CONDITIONING PROBLEM!

Call
JOHN FIELD-MAN
ON YOUR NEXT
WATER CONDITIONING
JOB

LELAND HAMNER CO.
P.O. Box 1065 - Capitol 9758 - Long Distance LD 2175
2211 PRESTON AVE. HOUSTON, TEXAS

Organization changes

Jones and Laughlin Steel Corporation announces the following changes in its organization:

Lewis M. Parsons has resigned as a director and a member of the executive committee, and as vice president in charge of sales.

Adam J. Hazlett, general manager of sales, has been elected vice president in charge of sales.

John W. Reavis, a member of the law firm of Jones, Day, Cockley and Reavis, of Cleveland, has been elected a director.

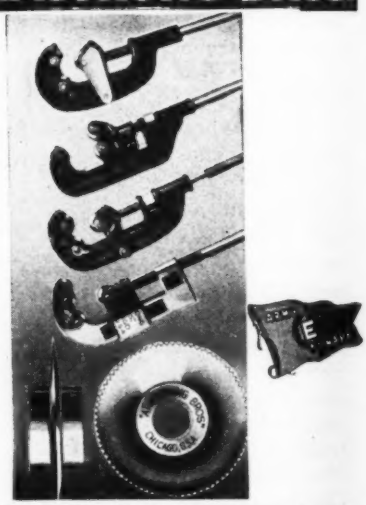
Offices moved

The chief administrative offices of the Pomona Pump division of the Joshua Hendy Iron Works have been moved to Sunnyvale, California, for a consolidation with the general administration of the company. Affected by the change are the sales, engineering, purchasing, and accounting departments.

Among the number of those moving their offices are Arnold Brown, sales manager; A. W. Moore, advertising manager, and Ralph Linderman, export manager.

All manufacturing activities will continue to be carried on in the Southern California plants at Pomona and Torrance, with Charles L. Barrett as plant manager for both.

Look for the Arm-and-Hammer
ARMSTRONG BROS.



All ARMSTRONG BROS. Pipe Cutters are made in all standard types. Each is a quality tool with hardened steel pins and rollers. "Saunder Type"—hardened end of thrust rod bears on inserted hard steel block (double life). In "Drop Forged" and "Combination" types, which take either 1 or 3 wheels, a replaceable hardened steel nut takes up thrust. In the "Barnes" type thrust rod threads through drop forged steel section.
ARMSTRONG BROS. Knife Blade Cutter Wheels (smooth or knurled) have thin penetrating edges that hold their keenness because they are machines from special vanadium tool steel, hardened and oil tempered. Fit all standard-make pipe cutters. . . . *Write for Catalog C-39a.*

ARMSTRONG BROS. TOOL CO.
"The Tool Holder People"
331 N. FRANCISCO AVE. • CHICAGO, U.S.A.
Eastern Warehouse & Sales: 199 Lafayette St., New York, N.Y.

Soviet views film

An indication of the increasing trade relations between the United States and the Soviet Union was emphasized recently in Washington where members of the Soviet Purchasing Commission attended a private showing of "Continuous Performance," an industrial film sponsored by The Cooper-Bessemer Corporation, Mount Vernon, Ohio, and Grove City, Pennsylvania.

The motion picture, which traces the development of the concern's engine production 111 years ago to its present place as one of the nation's leading producers of diesel and gas engines and compressor units, was enthusiastically received by the Russian officials.

Although the bulk of Cooper-Bessemer's production is allocated to the U. S. Navy, Army, Coast Guard, Maritime Commission, and home industries, they have supplied a large number of diesel-driven electric generating units for Russian rehabilitation and report that another large order for diesel engines is now in their hands.

Officials of Cooper-Bessemer who attended the Washington showing of the film were C. M. Reagle, vice president in charge of marine sales and manager of the firm's New York office; C. G. Cooper, manager of the Washington office; M. Henken, New York office; P. R. Letz, works manager, Mount Vernon, Ohio, plant, and J. H. Shields, home office sales engineer. Letz and Henken both speak the Russian language.

J. S. Fluor, dead

J. S. Fluor, Sr., founder of The Fluor Corporation, Ltd., Los Angeles, California, died at his home in Santa Ana, July 29.

Fluor came to the United States from Switzerland in 1887 at the age of 21 and entered the lumber business in Wisconsin. He went to California in 1912 as a contractor for the construction of compressor plants. In 1920, he built his first cooling tower.

J. S. Fluor

He has gradually been turning over the extensive business of The Fluor Corporation, Ltd., to his three sons. P. E. Fluor is president, J. S. Fluor, Jr., executive vice president and general manager, and F. C. Fluor, director and supervisor of equipment.

VOLUME PRODUCTION
to meet the Growing Demands of War and Industry for
WISCONSIN Air-Cooled ENGINES

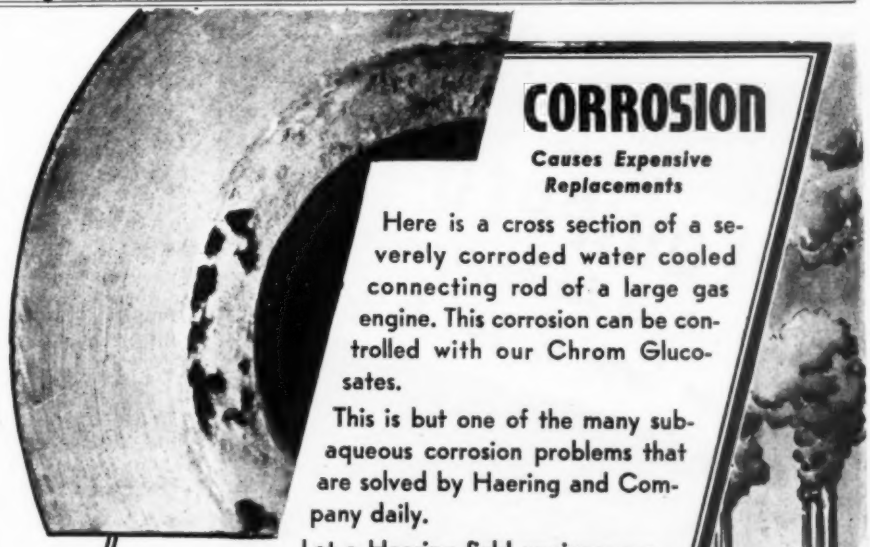
Highly systematized, progressive assembly of Wisconsin heavy-duty air-cooled engines keeps them coming off the production line in a steady, uninterrupted stream. Every operation is handled by a thoroughly trained workman who performs his specialized job with speed and skill.

The picture shows a run of Model VE-4, V-type, 4-cylinder engines going through . . . for power destinations on many types equipment. Perhaps one of these heavy-duty engines has been reserved for service on *your* equipment.

Most H.P. per pound

WISCONSIN MOTOR Corporation
MILWAUKEE 14 WISCONSIN U. S. A.
World's Largest Builders of Heavy-Duty Air-Cooled Engines

WRITE TO HARLEY SALES CO.
510 ATLAS BLDG., TULSA, OKLA.
M & M BLDG., HOUSTON, TEXAS
OIL FIELD DISTRIBUTOR FOR WISCONSIN ENGINES AND ALL TYPES OF UTILITY UNITS



CORROSION
Causes Expensive Replacements

Here is a cross section of a severely corroded water cooled connecting rod of a large gas engine. This corrosion can be controlled with our Chrom Glucosates.

This is but one of the many subaqueous corrosion problems that are solved by Haering and Company daily.

Let a Haering field engineer survey your corrosion problems and submit recommendations without any obligation on your part.

Write for "Scale and Corrosion Control in Aqueous Systems"

We Read Water

D. W. HAERING & CO., Inc.
GENERAL OFFICES:
205 West Wacker Drive, Chicago 6, Illinois

PUMPED BY
PEERLESS
daily—

300 GALLONS OF WATER
for every person in America

The combined daily productive capacity of the thousands of Peerless Deep Well Pumps is in excess of 36,000,000,000 gallons. This, figuratively speaking, is enough water to supply every person in America with 300 gallons per day. The colossal production of water, pumped by Peerless, is distributed among countless fields—for city water services, on farms and ranches for irrigation and livestock, and in factories and plants for critical war uses,—wherever a dependable water supply is needed. Engineers and experienced pump users made exhaustive study before selecting these thousands of Peerless Pumps. Their judgment is your protection.

PEERLESS PUMPS

PEERLESS PUMP DIVISION
Food Machinery Corporation

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Canton 6, Ohio • Other Factories:
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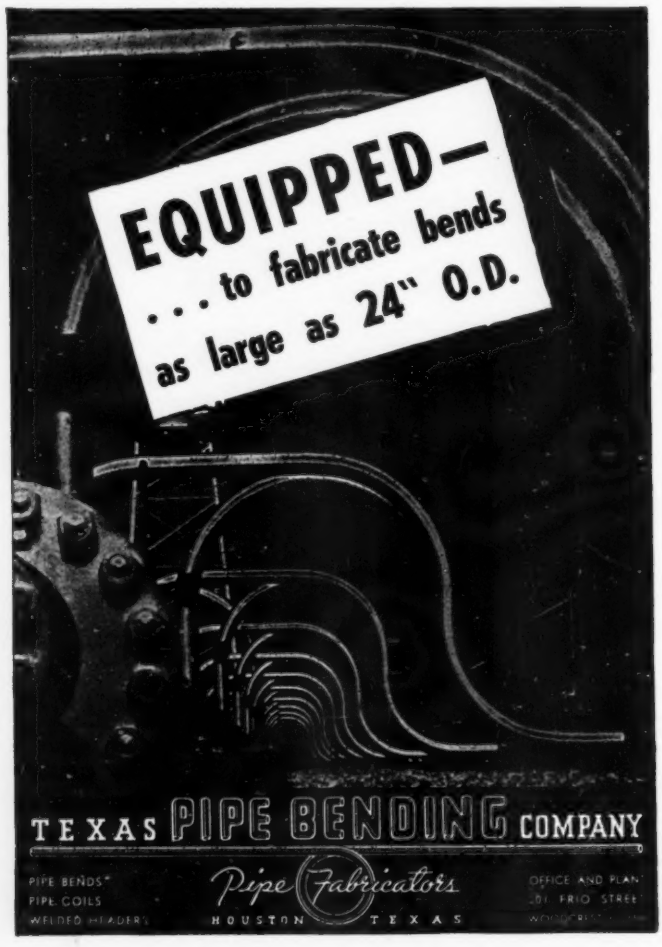

TEXAS PIPE BENDING COMPANY

PIPE BENDS
PIPE COILS
WELDED HEADERS

Pipe Fabricators

HOUSTON TEXAS

OFFICE AND PLANT
301 FRIO STREET

TRADE LITERATURE

What to Write For

▼ "Post War Prospects" is the title of a brochure published by Hamilton Bridge Company, Ltd., Hamilton, Canada, of which a limited number of copies is available to executives. The booklet is designed to give United States manufacturers of metal products a more intimate knowledge of the opportunities for them in Canada. Economic trends in the United States, Canada, and the United Kingdom are traced and discussed.

▼ A reference book of its products has been published for distribution by Harrisburg Steel Corporation, Harrisburg, Pennsylvania. Tables of S.A.E. specifications cover every one of the seamless and drop forged steel products. The handbook also has accurate illustrated descriptions of each item.

▼ Each one of Grant tools has separate literature, giving complete information of the part and its uses. Material on shale bits, reamers, bailers, cleaners, etc., will be mailed upon request to Grant Oil Tool Company, 2042 East Vernon Avenue, Los Angeles 11, California.

▼ The fifth edition of "Care and Handling of Sucker Rods" has just been announced by The S. M. Jones Company, 518 McBirney Building, Tulsa 3, Oklahoma, and is available upon request. Pocket size for greater convenience, the 28-page book is an interesting and useful field man's manual on sucker rods. Additions to the book include two valuable tables.

▼ A 15-page study of Panhandle Eastern Pipe Line Company common stock has been prepared by Kidder, Peabody and Company, 17 Wall Street, New York, and may be obtained by writing for a copy.

▼ Double flow horizontal induced draft cooling towers are the subject of an attractive new 34-page booklet released by The Marley Company, Inc., 3001 Fairfax Road, Kansas City, Kansas, and available upon request. Profuse illustrations of Marley double flow installations include many oil refineries and chemical plants.

▼ "Stepping Up the Value of Crudes in the Processing of Lubes," is the subject of a new brochure just published by The M. W. Kellogg Company. This publication is illustrated with flow sheets describing the following Kellogg processes: Propane deasphalting, propane dewaxing, phenol extraction, propane acid treating, propane fractionation, propane clay treatment, atmospheric-vacuum distillation units. Copies may be obtained by addressing the company at 225 Broadway, New York 7, N. Y.

▼ Reprints of an article describing the principles and operation of the gyroscopic multi-shot well surveying instrument are available upon request to Sperry-Sun Well Surveying Company, 1608 Walnut Street, Philadelphia 3, Pennsylvania. "Today's Interesting Tools" is the title of the paper.

▼ Charts and tables covering the heat conductivity and the physical and chemical properties of carbon, graphite, and "Karbate" materials are published in a new catalog section by National Carbon Company, Inc., 30 East 42nd Street, New York. The illustrated booklet, which shows the versatility of these materials in the design and execution of heating and cooling units, will be sent upon request.

▼ An educational booklet giving the basic fundamentals of hydraulic power and its application in modern oil well pumping is now available by request to Kobe, Inc., of Huntington Park, California. The booklet outlines the various steps in Kobe's fluid power system and shows how its operation makes possible new pumping advantages.

▼ "Lake Charles—How the Process Engineer Did It," is the feature article in the current issue of *The Kelloggram*, issued by The M. W. Kellogg Company, 225 Broadway, New York 7. The article tells the process engineering story of the huge refinery and synthetic rubber project recently completed by the Kellogg company for Cities Service Refining Company.

▼ "Fleet Welding," an entirely new method for increasing the speed of welding mild steel, is described in a 48-page illustrated booklet, No. 440, published by the Lincoln Electric Company, Cleveland, Ohio. Important subjects discussed in the manual include: Using "arc force" to increase welding speed; effect of penetration on welding costs; cost reduction with Fleet-Welding; factors affecting production speed, and other welding information. It may we had on request from the company.

Conference on engine trends

Many editors and writers of the industrial and business press gathered in Milwaukee recently for a conference on postwar trends in internal-combustion engines with special reference to increasing their power by means of supercharging. The hosts were Borg-Warner Corporation and their Milwaukee division, McCulloch Engineering Corporation.

The representatives of the publications met principal executives of Borg-Warner and McCulloch at luncheon at the Wisconsin Club. In the afternoon the McCulloch plant was visited and the manufacture and operation of superchargers on engines for land and marine uses were explained. This plant was built just before the war expressly for manufacturing superchargers and is equipped with a full complement of high precision machines. When the conference was resumed at 4:30 p. m. at the University Club, C. S. Davis, president of Borg-Warner Corporation, announced a change in the name of McCulloch Engineering Corporation to B-W Superchargers, Inc., effective at once. Davis and other executives talked briefly on the future of the internal combustion engine in the postwar world and the improvement in its power and efficiency that is being effected by supercharging.

According to Davis, wartime emphasis on engine performance has greatly stimulated interest in superchargers. He remarked that, although production today is devoted to entirely wartime needs, there lie ahead very interesting questions of reducing costs and increasing engine efficiency through the use of supercharging wherever internal-combustion engines are used. The tendency toward lighter weight engines will stimulate wider use of superchargers, in Davis' opinion.

Davis stated that the purchase of McCulloch Engineering Corporation by Borg-Warner marked their entry into the supercharger field, another step in their program of diversification and expansion in the automotive, aviation, tractor, and marine fields.

Executives of Borg-Warner Corporation see superchargers in the making in the plant of B-W Superchargers, Inc. Grouped around a gear grinding machine are (left to right): C. S. Davis, Chicago, president of Borg-Warner; June Breckenridge, machine operator; Philip D. Armour, Chicago, Borg-Warner director; R. J. Minshall, president of B-W Superchargers and one of the designers of the Flying Fortress.

Schwenk heads Busch-Sulzer

Edward B. Pollister, for many years president of the Busch-Sulzer Bros.-Diesel Engine Company, has retired and will take a complete rest from active work, it is announced by Adolphus Busch, III, chairman of the board. He is succeeded to the presidency by Norris H. Schwenk.

Schwenk's record of successful management of large business is long and impressive, including high executive positions with William Cramp and Sons Ship and Engine Building Company and its associated companies, including I. P. Morris Company; also with Pelton Waterwheel Company and De La Vergne Engine Company, of which he was president. These companies later became associated with the Baldwin Locomotive Works at Eddystone, Pennsylvania, of which Schwenk was an officer.

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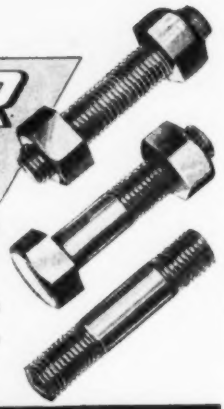

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McGill promoted by Westinghouse

C. B. Stainback, manager of the industrial department of the Westinghouse Electric and Manufacturing Company, has announced the appointment of Donald W. McGill as manager of the machinery electrification section of the department.

The new appointee succeeds L. F. A. Mitchell, who has returned to the Canadian Westinghouse Company as assistant to the vice president. McGill, formerly a staff member of the machinery electrification section, will be in charge of company application of electrical equipment and controls for industrial machinery.

E. H. Bristol of Foxboro dies

Edgar H. Bristol, president of The Foxboro Company, Foxboro, Massachusetts, and one of its founders, died of a heart attack on July 24 at his summer home at Falmouth Heights, Massachusetts.

Bristol was born in Naugatuck, Connecticut, March 7, 1871. He had unusual mechanical skill, and after completing his high school education, found employment as a machinist, later becoming a tool maker and subsequently production manager of the instrument company of which his father was president. With his brother, Bennet B. Bristol, he withdrew in 1908 to organize the Industrial Instrument Company, which, on January 1, 1914, became The Foxboro Company. Bristol maintained an active participation in the company's affairs, serving as its president throughout its history. He was also the president of the Foxboro National Bank.

He is survived by his widow, a son, Benjamin H. Bristol, 4 daughters and 16 grandchildren.

Mensing assistant treasurer

The National Supply Company announces the election of John B. Mensing as assistant treasurer.

Mensing has been associated with National for 25 years, beginning in the credit department at Toledo, Ohio, on March 17, 1919.

Later transfers took him to Fort Worth, Texas; Independence, Kansas, and then to the head office in Pittsburgh, where he was chief clerk of the Pittsburgh credit department for 10 years and later assistant to the treasurer.

To manage Standard Oil plant

Appointment of Carl H. Metz, Jr., as manager of The Standard Oil Company (Ohio) No. 1 refinery at Cleveland was announced by G. W. Hanneken, vice president in charge of manufacturing. Metz, who has been superintendent of the refinery since April, 1937, came to Sohio in August, 1927, as cracking coil stillman at No. 1. He was named foreman a year later and assistant superintendent in 1929. A native of South Carolina, he is a graduate of The Citadel and had spent three years with American-owned refineries in Mexico before joining Sohio.

I. L. Peterson, assistant superintendent of the No. 1 refinery since 1937 was named superintendent of maintenance and construction. Following his graduation from the University of Illinois in 1924, he joined Sohio as draftsman in the engineering department at the Toledo refinery, where he was named master mechanic in 1929. Peterson served in this capacity until May, 1936, when he was transferred to the home office as assistant to Hannekin in charge of mechanical operations. He became assistant superintendent a year later.

E. S. Bale, who has been in charge of the company's technical service division since September, 1939, was named superintendent of process at No. 1 refinery. A native of Cleveland, he served as refinery engineer in the East for five years following his graduation from Case School of Applied Science, and came to Sohio in January, 1939, as process control man at the Toledo refinery.

Joseph J. August, cracking coil foreman at No. 1 refinery for the past year succeeds Bale as chief of the technical service division.

Firm name changed

The name of the American-Terry Derrick Company, South Kearny, New Jersey, has been changed to the American Hoist and Derrick Company, Plant No. 2. The parent company is the American Hoist and Derrick Company, St. Paul, Minnesota.